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September 2003

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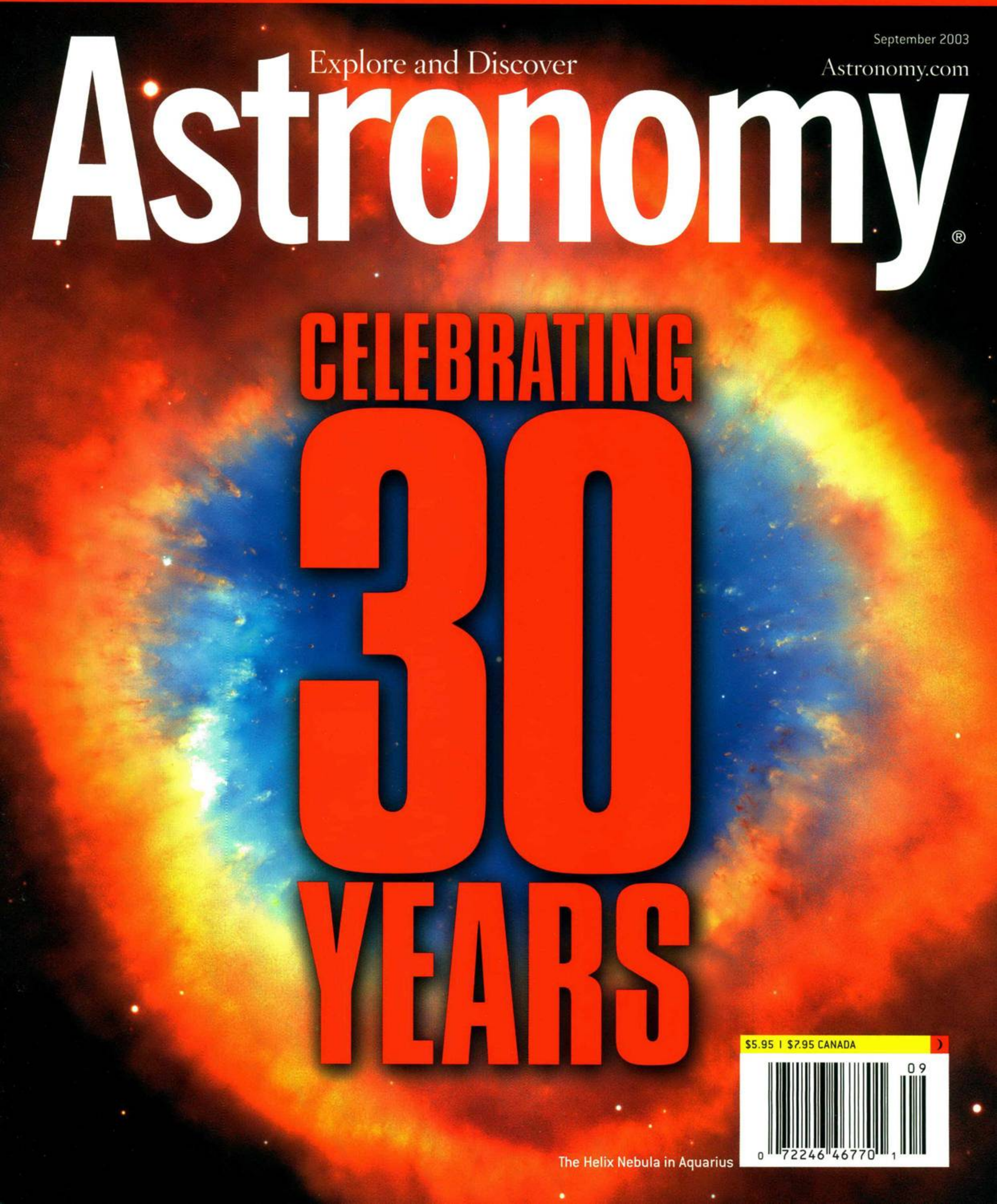


CELEBRATING 30 YEARS

$5.95 | $7.95 CANADA

The Helix Nebula in Aquarius

MEADE LXD55

Choose from six Meade Schmidt-Newtonians, each with Autostar® or Electronic Controller — from $579, *complete!*

Observe ***hundreds*** of galaxies, nebulae, and star clusters of all types ***your very first night out,*** and hundreds more the next night out, simply by pressing the Autostar GO TO pushbutton. Watch as the telescope fast-slews at 4.5°/second, locating each object — from the brightest to the most obscure — and placing it automatically, unerringly, and precisely in the telescopic field. Or choose one of the new EC-models with 4-speed, dual-axis Electronic Controller, telescopes upgradable at any time in the future to full GO TO status just by adding the Autostar hand controller.

Complete with #497 Autostar Controller:

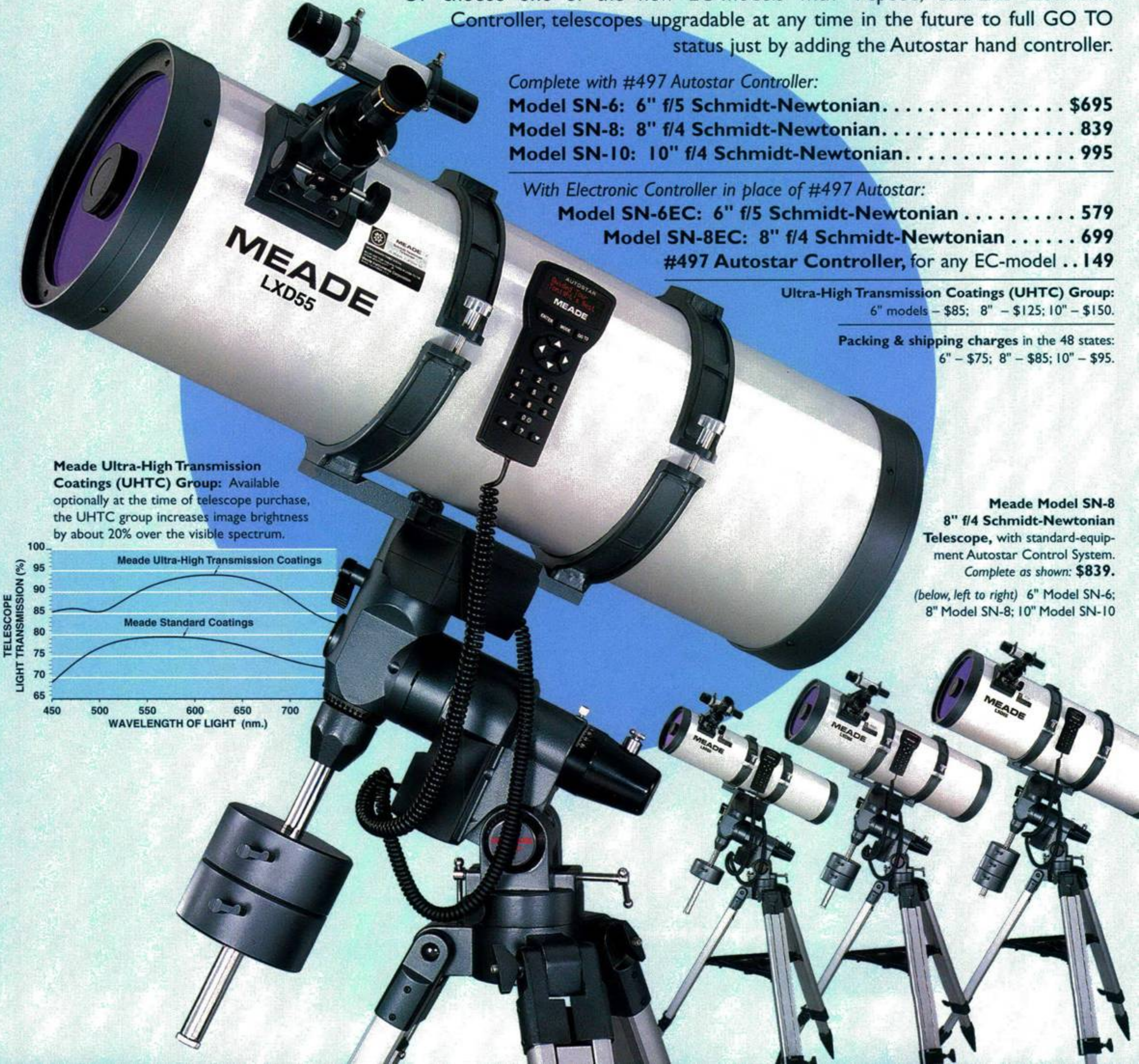
Model SN-6: 6" f/5 Schmidt-Newtonian	**$695**
Model SN-8: 8" f/4 Schmidt-Newtonian	**839**
Model SN-10: 10" f/4 Schmidt-Newtonian	**995**

With Electronic Controller in place of #497 Autostar:

Model SN-6EC: 6" f/5 Schmidt-Newtonian	**579**
Model SN-8EC: 8" f/4 Schmidt-Newtonian	**699**
#497 Autostar Controller, for any EC-model	**149**

Ultra-High Transmission Coatings (UHTC) Group: 6" models – $85; 8" – $125; 10" – $150.

Packing & shipping charges in the 48 states: 6" – $75; 8" – $85; 10" – $95.

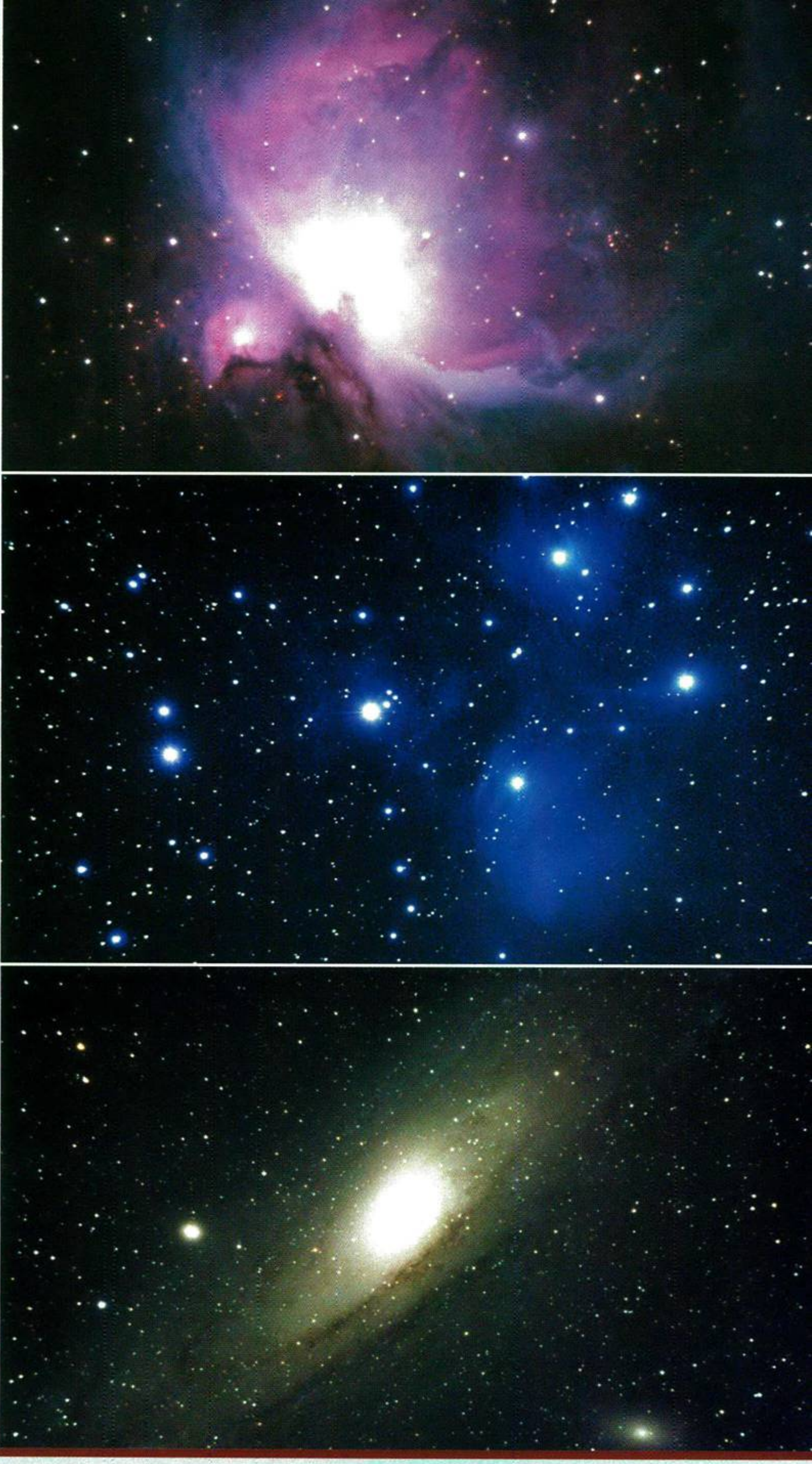

MEADE
LXD55
AUTOSTAR
MEADE

Meade Model SN-8 8" f/4 Schmidt-Newtonian Telescope, with standard-equipment Autostar Control System. *Complete as shown:* **$839.**

(below, left to right) 6" Model SN-6; 8" Model SN-8; 10" Model SN-10

Meade Ultra-High Transmission Coatings (UHTC) Group: Available optionally at the time of telescope purchase, the UHTC group increases image brightness by about 20% over the visible spectrum.

TELESCOPE LIGHT TRANSMISSION (%)
100
95
90
85
80
75
70
65
Meade Ultra-High Transmission Coatings
Meade Standard Coatings
450
500
550
600
650
700
WAVELENGTH OF LIGHT (nm.)



Images with the Meade Model SN-8 8" f/4 Schmidt-Newtonian telescope. To obtain the images at right H. Tokumitsu attached a Fuji FinePix S2Pro digital camera to the eyepiece-holder of his unmodified, factory-standard Meade Model SN-8. Tracking was accomplished on the LXD55 equatorial mount with the telescope's R.A. drive at the sidereal rate; no guiding was performed during the period of the exposures. *(top to bottom)* **The Great Nebula in Orion (M42)**; a composite of two 3-minute exposures. **The Pleiades (M45)**; a composite of two 2-minute exposures. **The Andromeda Galaxy (M31)**; a composite of four 3-minute exposures.

Many amateurs have used Meade LXD55-Series Schmidt-Newtonians to obtain stunning images of the Moon, planets, and deep-space with commonly-available consumer digital cameras. Meade "fast" flat-field optics, combined with smooth worm-gear tracking systems and the Autostar controller, permit even the beginning amateur to obtain images like those at right.

"Here in Japan, where Meade is the number one Schmidt-Cassegrain brand by a large quantity, your new LXD55 Schmidt-Newtonians have received a lot of attention. My personal choice was the 8" f/4 model, and I have been extremely pleased with the telescope in every respect. The equatorial mounting is solid and vibration-free for both high-magnification visual observing and for astrophotography. The optics are excellent, with sharp, round stellar diffraction images across the large field of view, and without the coma visible in fast parabolic Newtonians. Not only does the telescope give incredible views of deep-space objects and star fields, but it is a fine lunar and planetary instrument as well. Jupiter shows numerous cloud belts with a great deal of structure within the belts; Saturn's ring divisions and disk markings are very nicely resolved.

"My latest application of the 8" LXD55 Schmidt-Newtonian is to image deep-space objects with the Fuji FinePix S2Pro digital camera. Although this camera was developed as a consumer product, not as an astro-imaging device, the results I have obtained are most rewarding. I am enclosing a CD-ROM of some of my images. All images were obtained simply by attaching the camera body to the telescope, exposing ***unguided*** *for 2 to 3 minutes, and then compositing several images. In my 20 years as an amateur astronomer I have never obtained such impressive results with so little effort!*

— H. Tokumitsu, Tokyo, Japan.

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Astronomy · VOL. 31 · NO. 9

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ROBERT GENDLER

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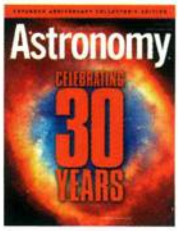

ON THE COVER
A breathtaking composite of the Helix Nebula in Aquarius serves as the backdrop for our 30th anniversary cover, designed by art director Tom Ford. The photograph combines data from the Hubble Space Telescope and the 0.9-meter telescope at Kitt Peak National Observatory, Arizona. STScI

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BY DAVID J. EICHER

Celebrating 30 years of *Astronomy*

Happy birthday, *Astronomy*. After 30 years of covering the greatest stories in the universe, the leading magazine in the field takes a pause to celebrate its existence. But not much of a pause. In your hands you hold a commemorative, 30th-anniversary issue of the magazine with coverage that looks back on the most exciting

three decades in the history of astronomy. We've added extra pages to accommodate the special editorial package, which commences with senior editor Rich Talcott's feature "30 years of great stories" on page 40.

Astronomy dates to August 1973, when a Wisconsin entrepreneur and recent college graduate enlisted his family to help launch the magazine. Steve Walther produced the first 48-page issue complete with articles by Jay Pasachoff, William Bruce Weaver, and John Sanford. Sadly, Walther was stricken later with a brain tumor and died in 1977, but his legacy continues. Our 30th-anniversary issue also features my personal reflection on the magazine's history on page 48. And Tom Ford, who worked on the magazine for several years before being named art director last year, contributes a stunning gallery of 30 great astronomical images from the past 30 years on page 52.

The issue is packed with other special stories, too. Astronomer Sallie Baliunas writes about another anniversary, the centennial of Mt. Wilson Observatory near Los Angeles on page 60. Sometimes called "America's Observatory," the site was the scene for some of the 20th century's most significant moments in science such as Edwin Hubble's landmark 1923 discovery.

Also included are Bob Naeye's review of the Yosemite Star Party, which is becoming a major event in California (page 96). We continue with world-renown astrophotographer Jack Newton's how-to secrets for CCD imaging success (page 100), Rod Pommier's primer on solar filters (page 106), and Steve Edberg's story on choosing the best eyepieces for every possible occasion (page 110). I hope you will greatly enjoy this oversized, information-packed issue. And I'd like to think that Steve Walther would approve.

MILWAUKEE SENTINEL

Monthly Aims At Heavens

STEVE WALTHER'S year-old magazine appears in the *Milwaukee Sentinel* on September 30, 1974. *ASTRONOMY:* WILLIAM ZUBACK

Yours truly,

Dave Eicher
Editor

Astronomy.
VoL. 31 No. 9

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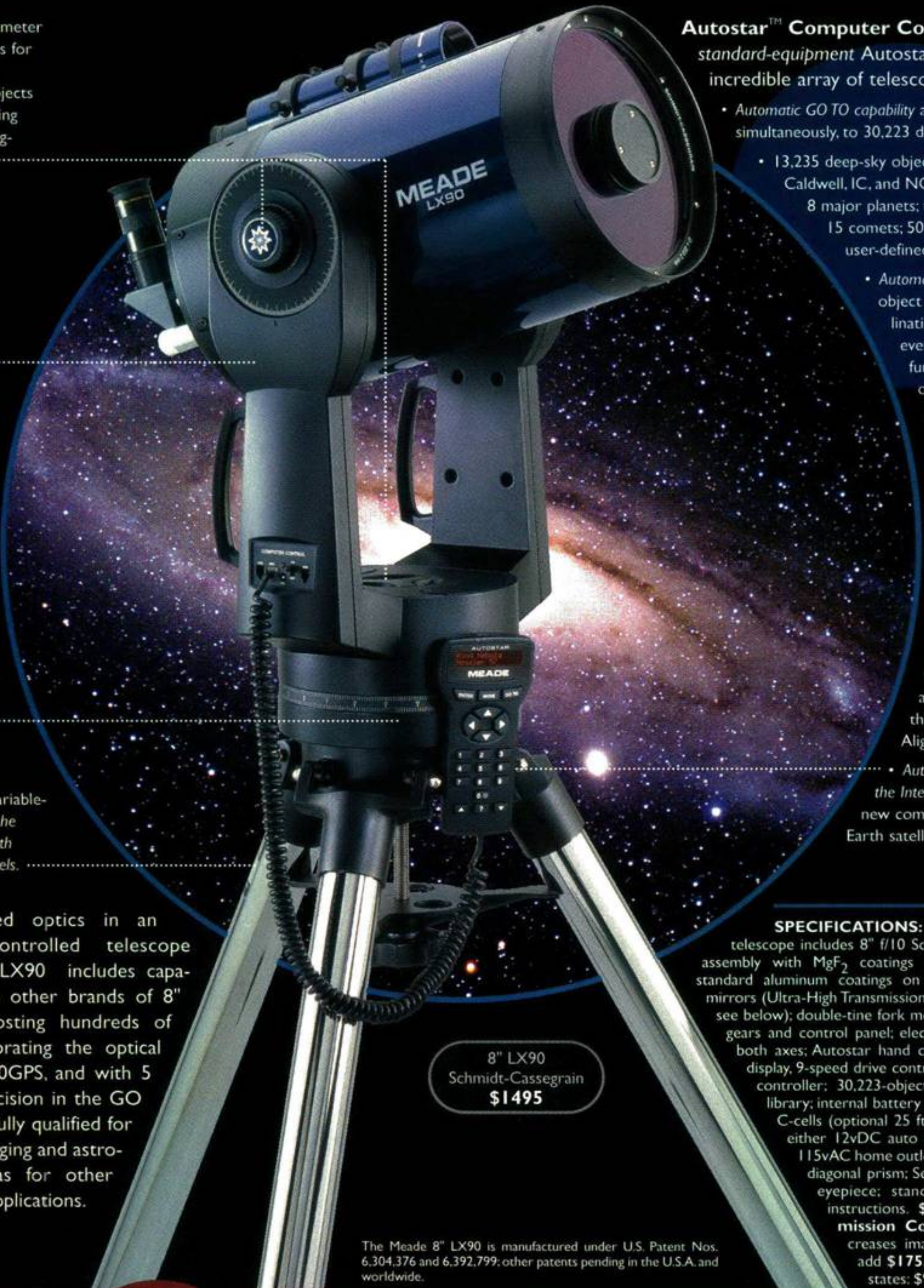

Worm gears of 4.9"-diameter on both telescope axes for smooth sidereal-rate tracking of celestial objects as well as precise guiding corrections during long-exposure imaging.

Die-cast-aluminum *double-tine* fork mount that rigidly supports the optical tube in all sky orientations.

The LX90 is powered for about 60 hours by 8 (user-supplied) C-cell batteries. Alternately, the telescope may be powered from an automobile cigarette lighter plug or from a standard 115vAC home outlet, using optionally available power cords.

Rigid chromed-steel variable-height field tripod — *the same tripod provided with Meade LX200GPS models.*

Autostar™ Computer Controller: The LX90's *standard-equipment* Autostar controller permits an incredible array of telescope features:

- *Automatic GO TO capability* at 6.5°/sec on both axes, simultaneously, to 30,223 database objects, including:
  - 13,235 deep-sky objects — the complete Messier, Caldwell, IC, and NGC catalogs; 16,888 stars; the 8 major planets; the Moon; 26 asteroids; 15 comets; 50 Earth satellites; plus 200 user-defined memory locations.
- *Automatic GO TO capability* to any object of known R.A. and Declination. Plus hundreds of special event menus, guided tours, utility functions, and telescope status options.
- *Nine selectable slew speeds:* 6.5°/sec, 3°/sec, and 1.5°/sec, as well as 128x, 64x, 16x, 8x, 2x, and 1x sidereal.
- *Control of the telescope* through your personal computer. (Requires optional #505 Connector Cable Set.)
- *Fast alignment of the telescope* using any of three alignment functions, including the Meade-proprietary Easy Align.
- *Autostar is fully upgradeable over the Internet:* add the positions of new comets, update the positions of Earth satellites, even add new software.

With diffraction-limited optics in an Autostar computer-controlled telescope system, the Meade 8" LX90 includes capabilities not available on other brands of 8" Schmidt-Cassegrains costing hundreds of dollars more. Incorporating the optical system of the 8" LX200GPS, and with 5 arc-minute pointing precision in the GO TO mode, the LX90 is fully qualified for long-exposure CCD imaging and astrophotography as well as for other advanced photo-visual applications.

8" LX90
Schmidt-Cassegrain
$1495

SPECIFICATIONS: 8" LX90 — Each complete telescope includes 8" f/10 Schmidt-Cassegrain optical tube assembly with MgF_2 coatings on the correcting lens and standard aluminum coatings on the primary and secondary mirrors (Ultra-High Transmission Coatings available optionally; see below); double-tine fork mount with dual-axis 4.9" worm gears and control panel; electric slow-motion controls on both axes; Autostar hand controller with digital readout display, 9-speed drive controls on both axes, and GO TO controller; 30,223-object onboard celestial software library; internal battery port accepts 8 (user-supplied) C-cells (optional 25 ft. cords permit powering from either 12vDC auto cigarette lighter plug or from 115vAC home outlet); 8 x 50mm viewfinder; 1.25" diagonal prism; Series 4000 Super Plössl 26mm eyepiece; standard field tripod; operating instructions. **$1495. Ultra-High Transmission Coatings (UHTC) group** increases image brightness by about 20%: add **$175.** Packing & shipping in the 48 states: $95.

The Meade 8" LX90 is manufactured under U.S. Patent Nos. 6,304,376 and 6,392,799; other patents pending in the U.S.A. and worldwide.

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Buy a $650 Super Plössl eyepiece set for your LX90 telescope for only $99! *See ad on page 8 for details!*

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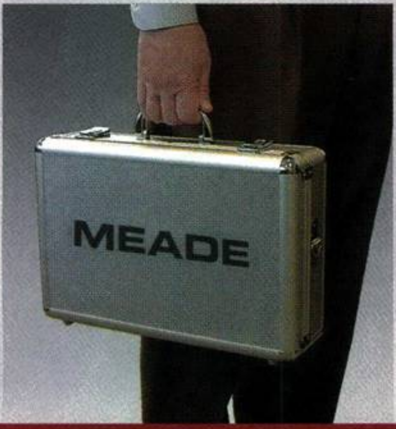
PLÖSSL 15mm MU
PLÖSSL 20mm MU
SUPER PLÖSSL 26mm
SUPER PLÖSSL 32mm
SUPER PLÖSSL 40mm

Now for a limited time, to celebrate Meade Instruments' 30 years in telescopes, you can buy a Meade telescope* and receive a full set of Meade premium-grade Super Plössl eyepieces for only $99 additional. Never before have we made such an incredible offer available for such a wide range of our most popular telescope models.

Choose from more than a dozen qualifying Meade telescopes *(see listing at right)*, mail us your check for $99, and we'll ship your Super Plössl eyepiece set directly to you. And we'll pack your eyepieces in the Meade #771 foam-lined aluminum carrying case, itself a $49.95 value if purchased separately. For complete details see the HOW TO ORDER box at right.

Designed and manufactured to exacting standards, Meade Series 4000 Super Plössl eyepieces deliver wide 52° apparent fields (44° for the SP40mm) with all of the resolution, edge-of-field sharpness, and color correction demanded in the most advanced visual applications. All eyepieces are brand-new and factory fresh; each is multi-coated, includes a soft rubber eyeguard, and is individually packed in a thread-on poly container. There are no finer general-purpose eyepieces available.



The Meade #771 aluminum carrying case, included with this special offer, provides rugged, secure storage for your Super Plössl eyepiece set.

This special offer includes the following eyepieces:

SP6.4mm	$79.95
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SP15mm	79.95
SP20mm	79.95
SP26mm	(standard equipment)**
SP32mm	99.95
SP40mm	99.95
#771 Aluminum Carrying Case	49.95
Total price if purchased separately:	**$649.60**

***Telescopes qualifying for this special offer include:**

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LX90, LX200GPS models: 8" LX90; 7", 8", 10", 12", 14", 16" LX200GPS

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1. Buy any qualifying Meade telescope from an authorized Meade dealer in the U.S.A.

2. Fax or mail a copy of your dealer's invoice, plus the completed warranty card packed with the telescope, along with your payment of $99 to Meade Instruments/Attn: Customer Service, and request the "$99 Eyepiece Offer." *Requests must include your complete shipping address and phone number.*

3. We will ship your eyepiece package to you within 30 days of our receipt of your request. Meade Instruments will pay for all shipping and insurance charges; safe arrival is guaranteed.

Other terms and conditions: Payment may be made by personal check (payable to Meade Instruments) or credit card (VISA or MasterCard). **California residents must add $7.67 sales tax, for a total payment of $106.67.** This special offer is valid only for new Meade telescopes ordered and received within the U.S.A. after 8/15/02 and is subject to change without notice. (Outside the U.S.A. contact your Meade international distributor.) There is no limit to the quantity of telescopes each person may order: each qualifying telescope is eligible to receive the special eyepiece package. Prices shown are suggested U.S. mail-order retail prices. **The SP26mm eyepiece (shown in photos above) is packed with each qualifying telescope as standard equipment.

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Messier 57
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ENTER
MODE
GO TO

Meade ETX-125AT
Shown with standard-equipment #497 Autostar Controller and #884 Deluxe Field Tripod.

Matchless diffraction-limited optics: *Sky & Telescope* described ETX-90 optics as "excellent…stellar diffraction patterns were virtually textbook-perfect…the Cassini Division in Saturn's rings popped into view despite the rings' low tilt…Epsilon Lyrae's component stars were cleanly split…the Moon was beautiful at any magnification, with black shadows contrasting sharply with illuminated features along the terminator…the mechanics of the optical tube assembly are also first rate."

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#497 Autostar Controller: The patented Meade Autostar controller brings automatic GO TO operation, plus dozens of additional menu options, to your fingertips, with a database of more than 30,000 celestial objects, including 5,386 galaxies, nebulae and star clusters from the Index Catalog (IC); 7,840 objects from the New General Catalog (NGC); 110 Messier objects; the major planets from Mercury to Pluto; and more.

#884 Deluxe Field Tripod: Constructed of strong, lightweight steel, the full-length Meade #884 Deluxe Field Tripod provides a rigid mounting platform for virtually any ETX observing application. Tripod height is adjustable for seated or standing observing. Use in either equatorial or altazimuth orientations; a graduated scale permits precise polar alignment. For Autostar applications, or for terrestrial observing, the tripod locks to 90°.

Each supplied with #497 Autostar Controller and #884 Deluxe Field Tripod:

ETX-90AT Astro Telescope	**$595**
ETX-105AT Astro Telescope	**795**
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Ultra-High Transmission Coatings (UHTC) group increases image brightness by about 20%: ETX-90AT– $50; ETX-105AT– $75; ETX-125AT– $95

Alternately, for the beginning-to-intermediate observer, the ETX-70AT is supplied with #494 Autostar Controller and #882 Field Tripod:

ETX-70AT Astro Telescope	**299**

Packing & shipping (ETX, Autostar, & Tripod): ETX-90AT — $30; ETX-105AT — $35; ETX-125AT — $40; ETX-70AT — $20.

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Series 4000™ Super Plössls
52° field; multi-coated

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or studying tenuous nebulosity in deep-space, Meade SP's deliver unmatched contrast and image sharpness. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal. **Super Plössls** (SP; 4-elements; 1.25"; 52°): **6.4, 9.7, 12.4, 15, 20, 26mm** each: **$79.95** (4.54); **32mm** (52°); **40mm** (44°) each: **99.95** (5.26); **56mm** (52°; 2") **199.95** (7.02)

Series 4000™ Super Wide Angle
67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above. **Super Wide Angle** (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (4.54); **18mm: 149.95** (4.54); **24.5mm: 179.95** (5.26); **32mm** (2"): **239.95** (7.02); **40mm** (2"): **299.95** (7.02)

Series 4000™ Ultra Wide Angle
84° field; multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians. **Ultra Wide Angle** (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (5.26); **6.7mm: 199.95** (5.26); **8.8mm** (1.25"/2"): **239.95** (7.02); **14mm** (1.25"/2"): **299.95** (7.02)

#1209 Zero Image-Shift Microfocuser

Identical to the Microfocuser supplied with Meade LX200GPS telescopes, but provided with a separate handbox for use with all other Meade SCT models (e.g., LX10, LX50, LX90, LX200) or for Schmidt-Cassegrains of other brands. Threads directly to the telescope's rear cell. Permits extremely precise focusing of the image during visual or photographic applications; during CCD applications maintains precise image centration on even the smallest CCD chips. Operates at four speeds, from extremely slow to fast; accepts both 2" and 1.25" eyepiece barrels. Requires 8 x AAA (user-supplied) batteries. **$249.95** (9.85)

CCD-Photo-Visual Flip-Mirror Systems

Use with any brand of CCD imager or for astrophotography with a 35mm camera. Flip mirror "down" to center the image while viewing with an eyepiece at 90°; flip mirror "up" to pass light on to CCD chip or 35mm camera film plane. Each unit includes: precision optical-flat Pyrex® mirror; 2-axis mirror-adjustment for precise image centering; extra-fine helicoid focusing of the eyepiece; extension tubes for 35mm camera (using T-Mount) or CCD imager (using either T-threads or 1.25" barrel). Threads to rear cells of all Schmidt-Cassegrain telescopes; may remain on telescope and used in place of diagonal prism for visual observing as well.

#644 Flip-Mirror System: Accepts any 1.25" eyepiece. Mirror clear aperture: 22mm. Use with CCD's up to Pictor 416XTE, ST-7, or AP1, or smaller; or visual observing with 1.25" eyepieces. **$149.95** (7.02)

#647 Flip-Mirror System: Accepts either 1.25" or 2" eyepieces. Mirror clear aperture: 40mm. Recommended for full-field 35mm astrophotography or with CCD's of any size, including all Meade Pictor Series through 1616XTE, or ST-4 through ST-10; or AP2, AP7; or for visual applications with 1.25" or 2" eyepieces. **249.95** (8.49)

#157 1.25" Adapter: Permits use of either Flip-Mirror on telescopes with 1.25" eyepiece-holders. (Requires approx. 2" additional focus travel with #644, 3" with #647.) **15.00** (3.86)

Series 4000™ f/3.3 CCD Focal Reducer/Field Flattener

Revolutionary 3-element Meade design permits ultrafast CCD imaging with **increased** edge-of-field resolution and color correction! Reduces CCD exposure times by up to 80%. Threads on to the rear cell of any Meade or Celestron Schmidt-Cassegrain. Converts f/10 Schmidt-Cassegrain telescopes to **f/3.3** and f/6.3 SCT's to **f/2.** Variable T-Adapter (included) allows range of f/ratios between f/3 and f/5 on f/10 SCT's and between f/1.9 and f/3.2 on f/6.3 SCT's. Use with CCD imagers of any brand and chip dimensions. Not for visual or photographic applications. Multi-coated; 41mm clear aperture. **$149.95** (5.26)

Series 4000™ f/6.3 Focal Reducer/ Field Flattener

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture. **$129.95** (5.26)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of longer focal-length Barlows. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated. **$47.95** (4.54)

Series 4000™ 2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm. **$79.95** (5.26)

Plössl 25mm Illuminated Reticle CCD Framing Ocular

Displays rectangular frames of all popular CCD chip sizes, including all Meade Pictor models; ST-4 through ST-8; AP1, AP2; and others. Shows precisely the image size and orientation that appear on CCD chip. Insert directly into telescope eyepiece-holder, or use with Flip-Mirror (*above*). Includes 4-element coated Plössl optics; lockable spacer ring to fix focus position; rubber eyecup; variable LED illumination control; batteries. 1.25". **$129.95** (4.54)

MA12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle; rubber eyecup. Wireless red LED illuminator and variable brightness control. 1.25". **Batteries included. $99.95** (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (5.26)

Series 4000 Photo-Visual Color Filters (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue — each **$14.95** (2.73)

Set #1–4 filters: #12, #23A, #58, #80A	**49.95** (4.54)
Set #2–4 filters: #11, #25A, #47, #82A	**49.95** (4.54)
Set #3–4 filters: #8, #21, #38A, #56	**49.95** (4.54)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **$16.95** (2.73)

#905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces. **$49.95** (5.26)

#911B
#908B
#911X
#908X

Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B–Threads into 1.25" eyepieces, 26mm dia. **79.95** (4.54)
#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. **99.95** (5.26)
#908N–Threads into 1.25" eyepieces, 26mm dia. **89.95** (4.54)
#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. **119.95** (5.26)

Series 4000 Oxygen-III Filters Observe diffuse emission and planetary nebulae as you never thought possible! Exclusive Meade *60-layer* interference coating technology isolates the 496nm and 501nm O-III lines to tremendously enhance observable nebular structural detail in all telescopes.

#908X–Threads into 1.25" eyepieces, 26mm dia. **99.95** (4.54)
#911X–Threads on to rear cell of Schmidt-Cassegrain telescopes; 36mm dia. **149.95** (5.26)

Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-35mm camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": $27.95; 1.25": $29.95 (3.86)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron Schmidt-Cassegrain. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your 35mm camera.

$39.95 (3.86)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography with 35mm cameras; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

$39.95 (3.86)

T-Adapters for Schmidt-Cassegrains

Rigidly couples 35mm camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

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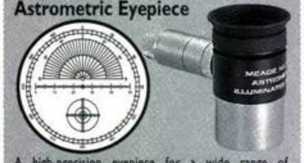
World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25". **$149.95** (6.14)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator. **$129.95** (5.26)

MA12mm Illuminated Reticle Astrometric Eyepiece



A high-precision eyepiece for a wide range of astronomical measurements. Includes four red-illuminated, laser-etched scales for measuring double star angular separations, position angles, planetary diameters, and lunar crater diameters, and for long-exposure photo-guiding. Modified Achromatic 3-element coated optics; diopter adjustment; rubber eyecup; variable LED illumination control; batteries. 1.25". **$119.95** (4.26)

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The finest zoom eyepiece available. High-resolution 7-element multi-coated optics, with 55° field at 8mm. Graduated scale in 1mm units indicates exact focal length in use. High-eyepoint yields comfortable observing even with eyeglasses. Internal zoom lenses move on the smoothest, most precisely-machined tracks yet developed for zoom optics. Performance is fully consistent with the finest fixed-focal length eyepieces. Threaded for filters; rubber eyecup; 1.25". **$219.95** (6.38)

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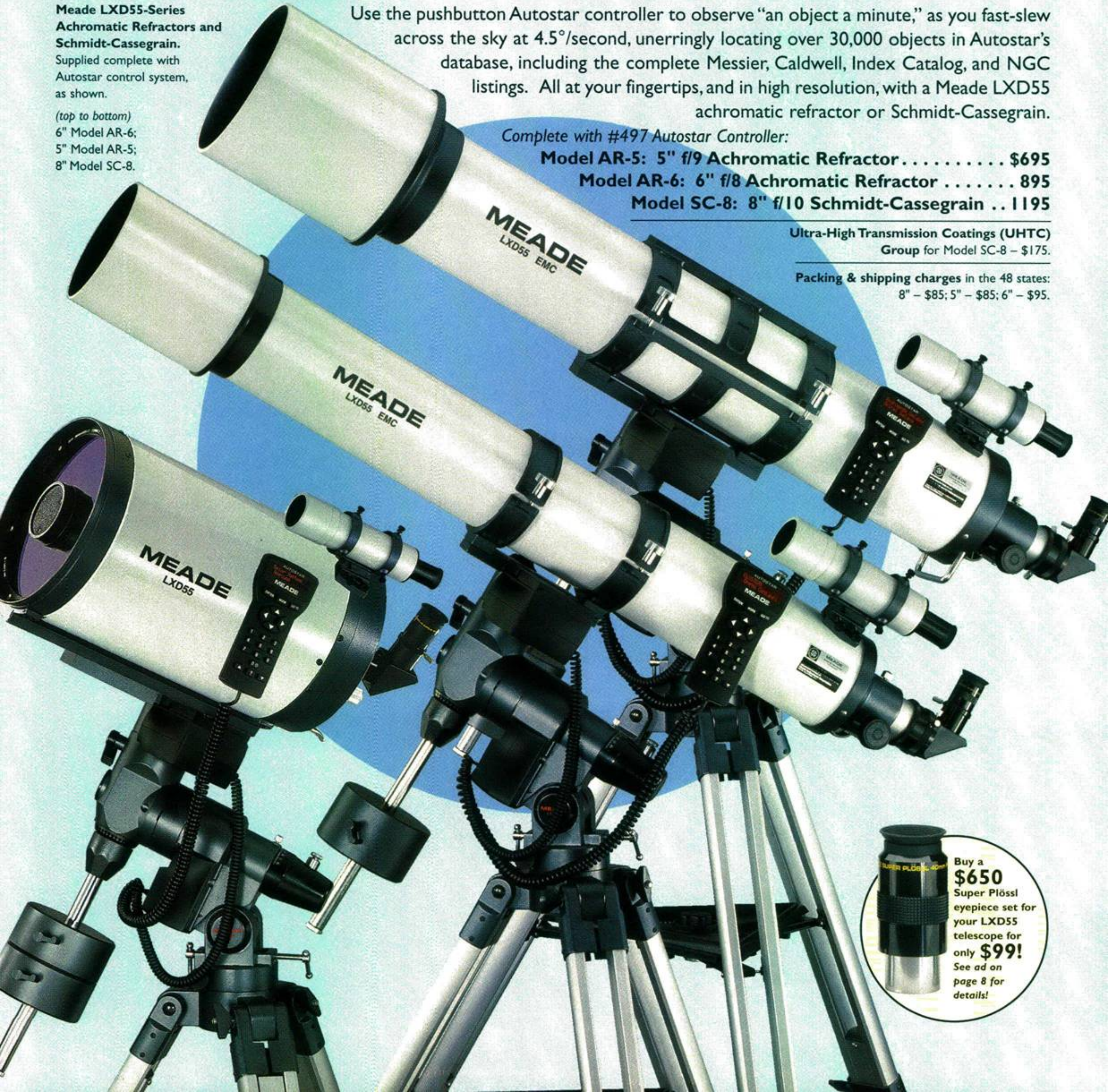

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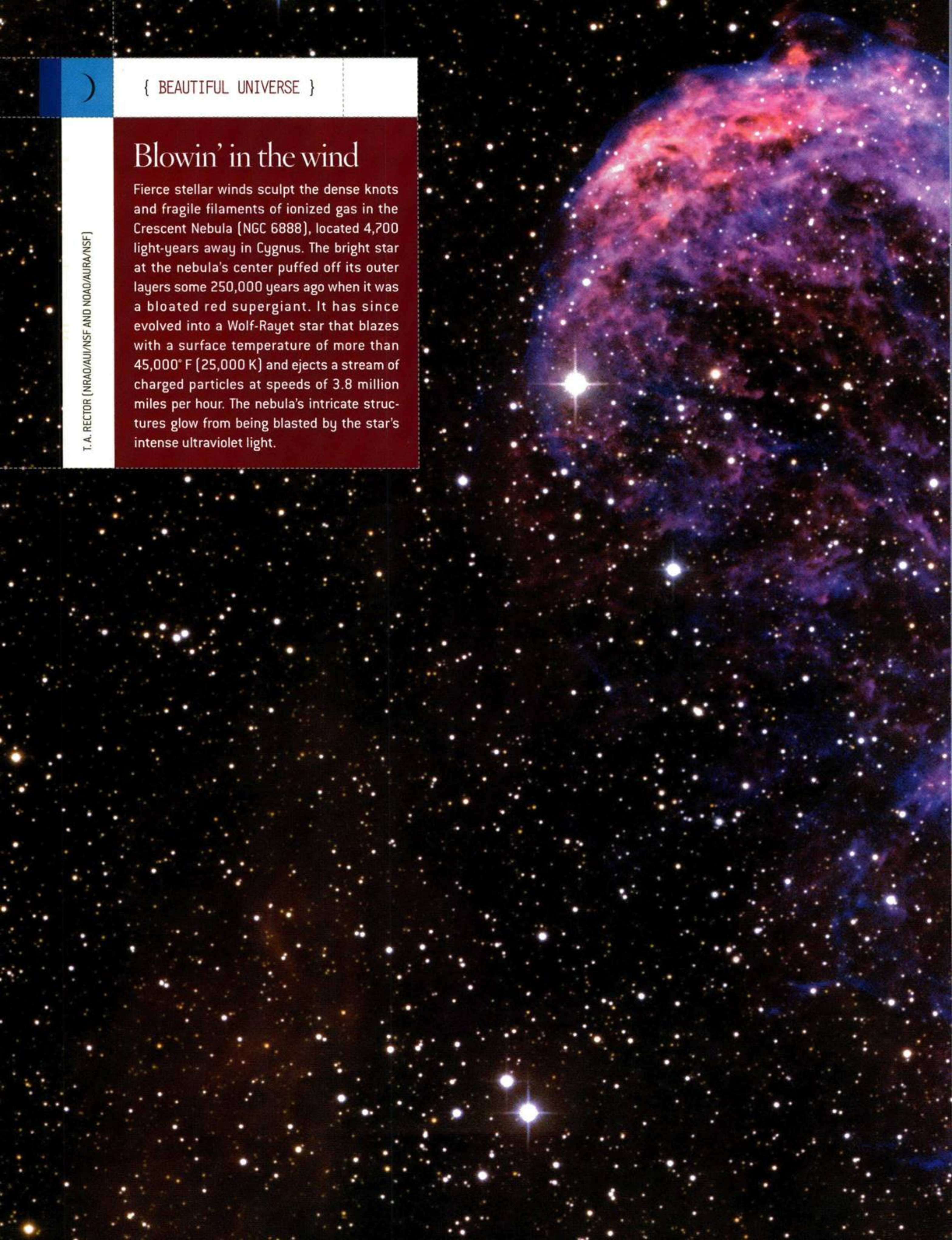

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.965" – $89.95 • 1.25" – $99.95 • Brandon 1.25" – $99.95 • 2" T-Threaded – $199.95 • 48mm – $199.95 • 72mm – $399.95 • Visual Back – $199.95 • 39mm Nikon – $299.95 • 43mm Nikon – $299.95

LUMICON UHC FILTER

The original Lumicon Ultra-High-Contrast narrow bandpass filter (24nm) isolates the two doubly-ionized oxygen lines (496 and 501nm lines) and the H-beta line (486nm) emitted by planetary and most emission nebulae. The result is superb views of the Orion, Lagoon, Swan and other extended nebulae. This makes the Lumicon UHC the best all-around dark-sky nebular filter available.

1.25" – $99.95 • Brandon 1.25" – $99.95 • 48mm – $199.95 • Visual Back SCT – $199.95

LUMICON OXYGEN III FILTER

The renowned, original Lumicon OIII narrow bandpass filter (11nm) isolates just the two doubly-ionized oxygen lines (496 and 501nm lines) emitted by planetary and extremely faint nebulae. Produces near-photographic views of the Veil, Ring, Dumbbell and Orion nebula, among many other objects. You will be amazed at what the OIII filter allows you to see!

1.25" – $99.95 • Brandon 1.25" – $99.95 • 48mm – $199.95 • Visual Back SCT – $199.95

LUMICON HYDROGEN-BETA FILTER

The Lumicon H-Beta Filter isolates only the Hydrogen-Beta line of the spectrum (486.5nm). Now you can view extremely faint, special objects such as the Horsehead, Cocoon and California Nebulae. In many cases, the Lumicon H-Beta Filter is the ONLY way to view these objects. A steady, transparent sky, with a minimum of an 8" or larger instrument, combined with the Lumicon H-Beta Filter, all make an unbeatable combination for viewing those "notch in the belt" objects.

1.25" – $99.95 • Brandon 1.25" – $99.95 • 48mm – $199.95 • Visual Back – $199.95

LUMICON HYDROGEN-ALPHA PASS FILTER, FOR BLACK AND WHITE DEEP-SKY PHOTOGRAPHY

The Lumicon H-Alpha Pass Filter is a powerful photographic aid in overcoming light pollution during deep-sky photography, and will help you achieve strikingly improved results in telephoto lens B&W astrophotography. It is ideally matched to hypersensitized 2415 film, and will reduce light pollution 10-fold, making it ideal for photography of faint emission nebulae.

Transmission for this sharp-cut-off filter is zero below 630nm, 90% at Hydrogen-Alpha 656nm, and 90-98% from 656nm to the near infrared. Both surfaces of filter have high-efficiency anti-reflection coatings to boost performance.

Exposures may be increased 2-10 times with the H-Alpha Pass Filter, depending on the faintness of the nebula.

48mm–$69.95 • 58mm–$79.95 • 77mm–$89.95 • 82mm–$99.95

48MM COLOR FILTERS

Used in lunar and planetary observing.

Red – $29.95 • Orange – $29.95 • Yellow – $29.95 • Green – $29.95 • Blue – $29.95 • Ultra-Violet (Clear) – $29.95 • Polarizer – $49.95 • Neutral Density – $39.95

1.25" lunar & planetary photo-visuals, world's best, coming soon.

LUMICON MINUS VIOLET FILTER FOR COLOR OR BLACK AND WHITE PHOTOGRAPHY

The Lumicon Minus Violet Filter greatly improves photographs taken through lens systems, producing pinpoint star images. It is especially recommended for all telephoto lenses. This filter is made from optically flat specially-made colored glass, and has anti-reflection coatings on both surfaces.

Recommended Films

All films can be used with the Minus Violet Filter; hypersensitized 2415 is the recommended B&W film, and is available directly from Lumicon or from any of Lumicon's authorized dealers.

Visual Use

The Minus Violet Filter can eliminate or greatly reduce the blue halo sometimes seen around stars through refracting telescopes. It is ideal for observing the moon and planets.

48mm – $49.95 • 58mm – $59.95 • 72mm – $69.95

LUMICON INFRARED BLOCKING FILTER

The Lumicon Infrared Blocking Filter completely blocks all infrared light above 750nm. Its versatile, anodized aluminum cell has 42mm male T-threads on one side and 48mm male threads with 42mm female T-threads, internal, on the other. Great for CCD camera infrared blocking purposes.

2" – $99.95

Infrared Blocking Filter 1.25" coming soon.

LUMICON UV DUST SEAL FOR MOST SCTs

The Lumicon UV Dust Seal keeps dust and insects out of your telescope. The seal mounts on the back of your SCT and accepts all attachments. It is an ultraviolet filter that passes all visible wavelengths of light with minimal absorption, no aberration, and no noticeable internal reflections. Fully Multi-Coated.

5-9.25" SCT / Mak – $39.95 • Meade 10/12/14" – $89.95 • Celestron 11/14" – $89.95

LUMICON COMET BAND FILTER

Lumicon's narrow visible bandpass (25nm) Comet Band Filter isolates the 501nm OIII and the 514nm Cyanogen lines. The high contrast gain of the filter reveals the delicate ionized tail of gaseous comets, allowing you to see their full extent. The Comet Band Filter also helps you to better distinguish gaseous comets from dusty comets which show little contrast gain. For dusty comets, use the **Lumicon Deep Sky Filter**.

Howard Brewington, famed comet discoverer says: "I discovered Comet Aarseth-Brewington, 1989a1, using the Lumicon Comet Band Filter. The filter doubled the contrast, making the comet very easy to spot." Be the person to discover the next "Comet of the Century" using the Lumicon Comet Band Filter.

1.25" – $99.95 • Brandon 1.25" – $99.95 • 48mm – $199.95 • Visual Back – $199.95

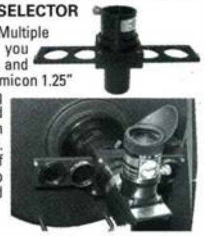
SOLAR PROMINENCE FILTERS

The 1.5 Ang. Lumicon Solar Prominence Filter system lets you see the awe-inspiring solar prominences jutting off the edge of the sun. Sunspots and bright filaments can also be seen on the sun's surface. The filter has a 2" barrel for insertion into 2" focusers, and can be easily adapted for 1.25". It also has camera T-threads and a viewing adapter for 1.25" eyepieces.

Solar Prominence Filter $699.95 • 58mm Energy Reject Prefilter – $169.95 • 77mm Energy Reject Prefilter – $199.95

Off-Axis Mask for 8" SCT – $69.95 • Off-Axis Mask for Meade 10" – $89.95 • Off-Axis Mask for C11 – $99.95 • Off-Axis Mask for 12" LX200 – $99.95 • Off-Axis Mask for C14 – $119.95 • Off-Axis Mask for M14 – $119.95 • Off-Axis Mask for 16" LX200 – $129.95

MULTIPLE FILTER SELECTOR



The Lumicon 1.25" Multiple Filter Selector lets you switch instantly back and forth between your Lumicon 1.25" filters without having to constantly thread and unthread them from your eyepieces. You may leave one of the 5 slots open to compare filtered and non-filtered views. – $129.95

EASY GUIDERS

All of Lumicon's famous off-axis guiders feature Lumicon's patented radial and rotational off-axis adjustments – combined with a large off-axis pick-off prism, making bright guide star selection a breeze.

CASSEGRAIN EASY GUIDER FOR 7" TO 9.25" SCTs

The Lumicon Cassegrain Easy Guider allows off-axis guiding with your Cassegrain telescope, reducing the f-ratio from f/10 to f/6.3 with a large, fully-coated focal reducing lens. The faster f-ratio, combined with the ease of finding and guiding on bright guide stars, minimizes guiding error, making for successful astrophotos. Threaded for 48mm filters. Specify camera type when ordering.

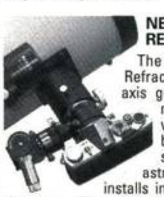
Celestron 5 – $249.95 • 7" Mak – $249.95 • 8" SCTs – $249.95 • Celestron 9.25" – $249.95

GIANT EASY GUIDER FOR 10" TO 16" SCTs

The Lumicon Giant Easy-Guider is a powerful photo/visual tool, utilizing an 80mm multicoated compression lens, reducing the f-ratio from f/10 to f/6.3, allowing you to take full advantage of your telescope's capabilities. Ideal for 35mm and 120 format film with 100% edge-to-edge illumination and pinpoint star images. All other off-axis guiders have prisms and focal reducing lenses a fraction the size of the Lumicon Giant Easy Guider's. Threaded for all Lumicon 48mm filters. Specify camera type when ordering.

10", 12", 14" and 16" Meade – $399.95 (Meade 16" LX200 requires adapter - $169.95) • 11" and 14" Celestron – $399.95

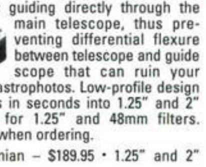
NEWTONIAN AND REFRACTOR EASY GUIDER



The Lumicon Newtonian and Refractor Easy Guiders allow off-axis guiding directly through the main telescope, thus preventing differential flexure between telescope and guide scope that can ruin your astrophotos. Low-profile design installs in seconds into 1.25" and 2" focusers. Threaded for 1.25" and 48mm filters. Specify camera type when ordering.

1.25" and 2" Newtonian – $189.95 • 1.25" and 2" Refractor – $189.95

LUMICON EASY GUIDER ACCESSORIES



- Newtonian Easy-Guider Focal Reducer Lens in Cell – $79.95
- Giant Easy-Guider Focal Reducer Lens in Cell – $199.95
- Giant Easy-Guider - No Lens – $319.95
- Cassegrain Easy-Guider - No Lens – $219.95

LUMICON 3X RELAY DIAGONAL FOR USE WITH EASY GUIDERS

Lumicon Relay Diagonal's 3x Barlow lens increases the guiding magnification in the off-axis portion of your Lumicon Easy-Guider, increasing off-axis guiding ease and precision. – $99.95

HYPER KITS

LUMICON FILM HYPERSENSITIZATION KITS

Film hypersensitization with a Lumicon Hyper-Kit super-dries your film's emulsion using nitrogen and hydrogen (Lumicon's Forming Gas: 8% prepurified hydrogen, 92% prep. nitrogen, removing ALL water vapor and oxygen molecules, thus thermally stabilizing the film's emulsion. The process also 'soaks' the emulsion with hydrogen, thus sensitizing the silver halide crystals, making them more sensitive to faint light. The combined effect reduces reciprocity failure of the film, allowing it to remain sensitive to light well beyond an hour instead of only a few minutes. Hypered film is a MUST for anyone who is serious about taking deep-sky photographs.

LUMICON MODEL 300 FILM HYPERSENSITIZATION KIT FOR 35MM AND 120 FILM

For simplest hypering with film still in its metal cassette, the Model 300 Hyper-Kit is easy in use and safe for your film. Operates with Lumicon's Forming gas at 30° C. Hypers film in two to five days.

Chamber Only – $249.95 • Film Hyper Kit – $375.95 • Hyper Kit O-Ring Set – $9.95

LUMICON MODEL 600 FILM HYPERSENSITIZATION KIT FOR 35MM AND 120 FILM

The versatile Lumicon Model 600 Hyper-Kit is capable of hypering film either while still in its metal cassette at 30° C, or more quickly with highest saturation on the open reel at 50° C. Super-dries and sensitizes the film's emulsion with Lumicon's Forming Gas.

Chamber Only – $299.95 • Film Hyper Kit – $475.95 • Hyper Kit O-Ring Set – $9.95 • Hyper Kit Hand Vacuum Pump – $39.95 • Hyper Kit Vacuum Pump Handle – $9.95

LUMICON MODEL 1200 FILM HYPERSENSITIZATION KIT FOR 35MM, 120, AND 4x5 FILM

Large-capacity Lumicon Model 1200 Hyper-Kit accepts 4x5 film. Kit is capable of hypering film in just 12-to-20 hours with highest saturation. Super-dries and sensitizes the film's emulsion with Lumicon's Forming Gas at either 30° or 50° Centigrade for simple or advanced modes of operation.

Chamber Only – $379.95 • Film Hyper Kit – $751.95 • 4x5 Plate Holders – $99.95 • Hyper Kit O-Ring Set – $9.95

HYPER KIT ACCESSORIES

- 4x5 Sheet Film holder – $99.95
- 35L Cylinder of Forming Gas – $145.95
- 30° C Temperature Sensor Probe – $99.95
- 50° C Temperature Sensor Probe – $99.95
- Temperature Controller – $139.95 • Electric Vacuum Pump – $349.95 • 220 V option on Vacuum Pump – $44.95 • 220V/110V Converter – $29.95 • Vac/Pressure Hose with Clamp – $9.95

ASTROPHOTOGRAPHY FILM

HYPERED FILMS

Use Lumicon Hypersensitized Film to take stunning astro photographs. Allows you to expose film on your favorite deep sky object far longer, with no fog buildup, than does non-hypersensitized film.

Fuji G800 – $19.95 • Fuji RD100 – $14.95 • TP2415 B&W – $19.95 • TP6415, 120 – $19.95 • Kodak P1600 – $24.95 • Kodak PPF400 – $19.95 • Kodak PPF400, 120 – $19.95

NON-HYPERED FILM

Lumicon's high-contrast, extremely fine-grained film. High quality for medium-format astrophotography.

TP2415, Bulk 150' Roll – $79.95 • TP2415, Normal 36 exposure – $11.95 • TP4415, 4x5" Normal 25 Sheets – $49.95 • SO-279 Vericolor Slide Film – $14.95 • Kodak 6415, Normal Film – $9.95 • Fuji G800, Normal Film – $9.95 • PPF400, 120, Normal Film – $11.95 • PPF400, 120, Normal Film - 5 pack – $49.95 • Kodak P1600, Normal Film – $19.95 • Fuji Sensia RD100, Normal Film – $9.95

FILM DEVELOPING MATERIALS

- Film Changing Bag – $ 16.95
- Kodak D19 B&W Developer – $ 19.95
- Patterson film developing tank – $19.95

DIAGONALS

ENHANCED ALUMINUM STAR DIAGONALS

The Lumicon Enhanced Aluminum Star Diagonal reflects 96 to 97 percent of the light from the telescope's primary optics into your eyepiece. Its single 1/10 wave precision-polished surface is superior to the three surfaces of prism diagonals, and its enhanced coating is more durable than a standard aluminum coating. Lumicon collimates each star diagonal using a double-pass collimator, ensuring that the light reflected from the diagonal is perfectly perpendicular to the telescope's optical axis.

1.25" – $99.95 • 2" – $189.95

LUMIBRITE STAR DIAGONAL

The Lumicon LumiBrite Dielectric-Coated Diagonal reflects >98 percent of the light from the telescope's primary optics into your eyepiece. Not only is the Dielectric Coating more durable than a standard aluminum coating, it is also smoother, resulting in higher image contrast. 1.25" – $149.95 • 2" – $239.95

SKY VECTOR

The Lumicon Sky Vector is a state-of-the-art digital setting circle system, providing virtually any astronomical telescope, whether equatorial or altazimuth, with a continuous, real-time digital readout of right ascension and declination coordinates. With the Sky Vector, you will be able to find objects even faster than with most fully computer-driven telescopes. Its alphanumeric display uses a simple, easy-to-read scrolling text format. There is no need to polar align or to enter Latitude, Longitude, Date, Altitude, and Sidereal time – just initialize on one or two stars and you're ready to go!

SKY VECTOR 1

The Lumicon Sky Vector 1 features: One- or two-star initialization; 4000-step encoders for high-resolution accuracy (0.09 deg.); Digital Right Ascension coordinate readout to 1 minute; Digital Declination readout to 10 arc-minutes; Guide mode for guiding you to the selected object in current memory; Database containing over 220 of the finest objects in the sky, including the famed "Messier Catalog."

Complete Set – $349.95 • Kit only – $269.95

LUMICON NGC SKY VECTOR

The Lumicon NGC Sky Vector has all the features of the Sky Vector 1, plus a large 12,000-object database, higher resolution display modes, IDENTIFY mode, and current constellation and chart number displays - all on a 16-digit red LED display. It can be integrated with a personal computer for display of celestial object coordinates.

Complete Set – $489.95 • Kit only – $419.95 • Serial Cable – $29.95

SKY VECTOR UPGRADES

- Upgrade 3.65 Chip Set for NGC Sky Vector. – $59.95
- 8192-Step Encoder (Set of 2). Can be purchased separately or in place of the standard 4000 step encoders. – $29.95

LUMICON SKY VECTOR HARDWARE PACKAGES

Lumicon Sky Vector Hardware Package for Meade and Celestron SCTs includes: declination encoder bracket, right ascension encoder holder, encoder shaft holders, Allen wrench, and instructions.

Lumicon Sky Vector Hardware Package for Dobsonian telescopes includes: brass azimuth bolt, stainless steel azimuth encoder bracket, aluminum altitude-encoder-shaft holder, stainless steel altitude encoder bracket, 10 wood screws, Allen wrench, and instructions.

C5+ – $79.95 • C8 – $69.95 • Celestar 8 – $79.95 • Celestar 8 Dlx – $79.95 • G8/G11 – $349.95 • Ultima 8 – $79.95 • Ultima 11 – $99.95 • C11 – $79.95 • C14 – $129.95 • Meade 2080 – $69.95 • 2120 – $79.95 • 8" Dob – $69.95 • 10" Dob – $69.95 • 12/13" Dob – $79.95 • 16/17" Dob – $89.95 • CI700 – $299.95

RICHFIELD VIEWERS

RICHFIELD VIEWER FOR 7" TO 9.25" SCTs

The Lumicon Richfield Viewer takes your Schmidt-Cassegrain's f/10 optics and reduces them to f/6.3 for beautiful wide-field views. Its fully-coated 50mm diameter focal reducing lens has a larger clear aperture and less coma than higher-priced focal reducers on the market, providing superb unvignetted views. Barrel accepts 2" star diagonals. Comes with an aluminum 2"-1.25" eyepiece reducer, threaded for 48mm filters. – $99.95

RICHFIELD VIEWER, THREADED FOR 7" TO 9.25" SCTs

Threads directly into telescope. – $99.95

RICHFIELD VIEWER, SLIDE-ON, FOR 7" TO 9.25" SCTs

For attachment onto SCTs that have the Lumicon Easy-Guider threaded attachment ring in place. Slides over attachment ring. – $99.95

GIANT RICH-FIELD VIEWERS

LUMICON GIANT RICH-FIELD VIEWER FOR LARGE SCTs

Takes your large Schmidt-Cassegrain f/10 optics and reduces them to f/6.5 for the widest possible views of large galaxies like M31, M33 and NGC 253, and pairs of galaxies like M81 and M82. Moving the 80mm diameter focal reducing lens to the forward position in the Rich-Field Viewer body yields an even wider field. Comes with a 2"-1.25" eyepiece reducer, threaded for 48mm filters.

10" SCTs – $279.95 • Celestron 11" – $279.95 • 12" SCTs – $279.95

LUMICON 2.5X CCD COMPRESSOR

This cost-effective, fully-coated lens widens the telescope field and yields pinpoint star images for small to medium-size CCD cameras. Has male threads for standard 1.25" eyepieces or camera-type barrels. – $129.95

LUMICON 48MM COMA CORRECTOR/FIELD FLATTENER FOR NEWTONIAN EASY GUIDER OR 2" EYEPIECE

The Lumicon Coma Corrector / Field Flattener Lens dramatically reduces coma and flattens the field when used, in particular, with f/3.5 to f/6 Newtonian telescopes. It makes off-axis star images much smaller, thus improving photographic quality and making guiding much easier. Free of all chromatic aberration and fully multicoated to prevent ghost images. Can be used on all 48mm threaded accessories. Neither shrinks nor magnifies the image. – $239.95

LUMICON 1.5x–1.8x MULTIPLIER/FIELD FLATTENER

The Lumicon Multiplier / Field Flattener Lens has been custom computer-designed to increase image scale with the flattest field possible for photography and visual use with fast Newtonian Telescopes. This lens is suitable for use with f/3.5 to f/6 systems. Fully multicoated for maximum light transmission. – $259.95

FINDERSCOPE

Lumicon 80mm SuperFinder for Right-Angle viewing. This finder telescope actually lets you see many of the deep-sky objects you are looking for, complementing any telescope having 8 or more inches of aperture. It also makes for a wonderful rich-field telescope for beautiful views of the Milky Way. Comes with 25mm, 1.25" cross-hair eyepiece and helical drawtube-type focuser.

50mm RA Finder - Body Only – $79.95 • 50mm RA Finder - Complete – $149.95 • 50mm Straight-Thru Finder - Body Only – $79.95 • 50mm Straight-Thru Finder - complete – $119.95 • 80mm Right Angle SuperFinder - Body Only – $199.95 • 80mm Right Angle SuperFinder with Tripod Block – $219.95 • 80mm Right Angle SuperFinder - Complete – $299.95 • 80mm Straight-Thru SuperFinder - Body Only – $199.95

FINDERSCOPE BRACKETS

This two-ring finder bracket firmly holds finderscopes to your telescope while allowing precise alignment with the main optical axis. The base is radius-cut to fit snugly against the telescope's main tube, and the dovetail groove makes it easy to install or remove the finderscope from the base. Fastens in brand name SCT telescope mounting holes.

- 50mm Finder Bracket, 8", 10/11", and 14" – $49.95
- 80mm Finder Bracket, 8", 10/11", and 14" – $59.95

- Universal Dovetail Bracket for 50mm finder – $39.95
- 2 traditional universal ring-type brackets for 50mm finder – $19.95

LUMICON 25MM CROSS-HAIR FINDER EYEPIECE

This well-made 25mm, 1.25" Kellner single-crosshair finderscope eyepiece is ideally suited for Lumicon's 50mm and 80mm SuperFinders. High contrast and flat field. Non-illuminated. – $69.95

GUIDING EYEPIECE

LUMICON GUIDING EYEPIECE WITH RETICLE ILLUMINATOR

Lumicon's top-quality 12.5mm, 1.25" Orthoscopic eyepiece with focusable dual cross hair for precision guiding. Incorporates new state-of-the-art cordless Reticle Illuminator, featuring rheostatic brightness control and on/off switch.

12.5mm, 1.25" Illuminated Reticle E.P. – $149.95 • Pulseguider Illuminator – $42.95

BINOVIEW

LUMICON BINOVIEW

These new high-quality German-made binoviews employ Grade-A BK 7 crown glass for its precision-polished prisms. Ordinarily, BaK 4 is used as a recourse to improve color correction, but in these binoviews color correction is so good that we may use the most transparent, homogeneous, bubble-free crown glass available – BK 7. Clear aperture is 22mm. Its straight-through design employs superior roof prisms for image erection. Each prism surface is multicoated for the highest transmission of light and freedom from ghosts. Focuser travel is 20mm. – $699.95

VISUAL AND PHOTOGRAPHIC ACCESSORIES

PHOTOGRAPHIC ADAPTERS

1.25" Prime Focus Adapter – $24.95 • 2" Accessory Adapter for Celestron Classic Refractors – $39.95 • 2" Accessory Adapter for Celestron Fluorite Refractors – $39.95 • .96" Prime Focus Adapter – $19.95 • Basic Camera Adapter 1.25" – $39.95 • Basic Camera Adapter .965" – $39.95 • Adapter to mount Mamiya 645 Camera to 2" – $149.95 • 2" to T-thread adapter – $29.95 • Tele-Extender – $29.95

VISUAL ADAPTERS

1" Thread-in extension tube, 1.25" – $19.95 • 1.25" Focuser to .96" Eyepiece Adpter – $24.95 • 2" Length drop-in Extension Tube 1.25" – $19.95 • 4.5" Length Drop-in Extension Tube, 1.25" – $29.95 • 2" Long Thread-in Extension tube, 2" Diameter – $24.95 • 2" Long, 2" Diameter Drop-in Extension Tube – $24.95 • 3" Long, 2" Diameter Drop-in Extension Tube – $24.95 • 2" to 1.25" Reducer – $24.95 • 2" Accessory Adapter for C6 – $39.95 • 2" Accessory Adapter for Schmidt Cassegrains – $39.95 • 2" Accessory Adapter for Celestron Classic Refractors – $39.95 • 2" Accessory Adapter for Celestron Fluorite Refractors – $39.95 • Adapter for .96" focuser and 1.25" Eyepiece – $24.95 • f/10 Viewing Adapter for Giant Easy Guider – $89.95 • Adapter for Meade 2" Thread-on diagonal to Cass. Easy Guider – $39.95 • Adapter for Meade 2" Thread-on diagonal to Giant Easy Guider – $49.95 • Adapter to hold 1.25" Eyepiece on T-thread – $29.95 • Adapter to hold 2" eyepiece on T-thread – $49.95

EASY GUIDER ADAPTERS

Adapter to mount Hasselblad Camera to Giant Guider – $449.95 • Adapter to mount Pentax 645 Camera to Giant Guider – $169.95 • Adapter to mount Pentax 6x7 Camera to Giant Guider – $149.95 • 16" LX200 adapter for Giant Guider – $169.95 • Adapter to mount Hasselblad Camera to Cass. Easy Guider – $349.95 • Adapter to mount Pentax 645 Camera to Cass. Easy Guider – $159.95 • Adapter to mount Pentax 6x7 Camera to Cass. Easy Guider – $139.95

STEP RINGS

48mm to 46mm – $11.95 • 48mm to 49mm – $11.95 • 49mm to 48mm – $11.95 • 52mm to 48mm – $11.95 • 52mm to 58mm – $11.95 • 55mm to 48mm – $12.95 • 55mm to 58mm – $12.95 • 58mm to 48mm – $12.95 • 62mm to 58mm – $12.95 • 62mm to 72mm – $14.95 • 67mm to 62mm – $15.95 • 67mm to 72mm – $15.95 • 67mm to 77mm – $15.95 • 72mm to 67mm – $15.95 • 72mm to 77mm – $15.95 • 77mm to 67mm – $15.95 • 77mm to 72mm – $15.95 • 82mm to 77mm – $15.95

LUMICON ADJUSTABLE PIGGYBACK MOUNTS

Lumicon Deluxe Piggyback Mounts allow you to mount the Lumicon SuperFinder, other small telescopes, or cameras having 1/4-20 threaded mounting blocks, onto medium and large telescopes. The Piggyback Mounts are adjustable in altitude and azimuth, thus allowing you to align your optics with the optics of your main telescope. Each of the four available Piggyback mount bases have their own radius cut, allowing a solid flush mount to your telescope's main tube.

6" – $59.95 • 8" SCT – $59.95 • 10/11" SCT – $59.95 • Celestron C14 – $59.95

MISCELLANEOUS ACCESSORIES

HELICAL FOCUSERS

Lumicon Helical Focuser, 1.25" and 2.00" for tube O.D.s 7.5", 9.5", 12.5", 16", and 20". Also flat base or specially for Odyssey.

1.25" Helical Focusers 7.5" – $69.95 • 1.25" Helical Focusers 9.5" – $69.95 • 1.25" Helical Focusers 12.5" – $69.95 • 1.25" Helical Focusers 16" – $69.95 • 1.25" Helical Focusers 20" – $69.95 • 1.25" Helical Focusers, Flat Base – $69.95 • 1.25" Helical Focusers, Odyssey – $69.95 • 2.00" Helical Focusers 7.5" – $99.95 • 2.00" Helical Focusers 9.5" – $99.95 • 2.00" Helical Focusers 12.5" – $99.95 • 2.00" Helical Focusers 16" – $99.95 • 2.00" Helical Focusers 20" – $99.95 • 2.00" Helical Focusers, Flat Base – $99.95 • 2.00" Helical Focusers, Odyssey – $99.95

VINYL DUST COVERS AND PLUGS

1.25" – $6.95 • 1.3" – $6.95 • 1.5" – $6.95 • 2" – $6.95 • 2.1" – $7.95 *(all these prices for a set of four)* • 5.5" – $7.95 • 6.7" – $9.95 • 7.5" – $12.95 • 9.5" – $17.95 • 10.3" – $17.95 • 12.5" – $23.95 • 12.8" $23.95 • 15" – $35.95 • 15.6" – $36.95 • 16" – $37.95 • 19" – $42.95 • 21" – $45.95 • 1.25" Plastic Dust Plug – $6.95 • 2" Plastic Dust Plug – $8.95 • 3.5" Plastic Dust Plug – $6.95 *(all these prices for each piece).*

LUMICON LUMILITE RED LED FLASHLIGHT

The Lumicon Red LED Flashlight not only provides the proper illumination for star atlases, but also for walking in the dark when held at or below belt level. Has built-in resistor for energy conservation – If you accidentally leave it on when you pack up, its batteries will still be almost as good as new in the morning! Great for astronomers, submariners or pilots who need to preserve their night vision. – $14.95

BARLOWS

Lumicon 2x Barlow 1.25" – $39.95
Lumicon 2x Barlow 1.25" Thread-in – $79.95

12" CAMERA CABLE RELEASE

Self-locking 12" Camera Cable Release for timed exposure. This high quality vinyl-covered cable release prevents camera shutter vibrations on long exposure photographs – a must for astrophotography. – $19.95

COLLIMATORS

Lumicon Cheshire Collimator for Laser – $39.95

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Return to the Moon

Paul Spudis's recommendations in "Harvest the Moon" (June 2003) are just what's needed to help the United States recover its purpose and direction in space. The Office of Exploration at the Johnson Space Center's plan for a return mission to the Moon seems so right; it should force NASA to reevaluate its priorities.

Yes, there is probably evidence of life on Mars, and there's no reason we can't continue to probe for it robotically. But manned missions to Mars will be more successful if they can benefit from experience gained from outposts on the Moon.

Now that water has been discovered on the Moon, many elements — including the much-debated value of the International Space Station — seem to be falling into place. After Apollo, we know a small starter base on the Moon is possible; surely at this point, it's worth a try. **GEORGE STACEY,** CALGARY, ALBERTA, CANADA

Spudis sidesteps one critical problem that must be overcome to realize his vision of human space activity: We need something better than chemical propellants for the most difficult part of any space endeavor — the ascent into low-Earth orbit.

The most efficient propellants used today are liquid oxygen and hydrogen. What is rarely stated, however, is that they come within 10 percent of the theoretical performance limit of any chemical propellant combination. It takes about 6 pounds of these propellants to produce the energy needed to orbit 1 pound of anything — including more propellant. In any space launch, the weight of the payload that reaches orbit is only a few percent of the gross liftoff weight of the launch vehicle that put it there.

How practical do you think it would be for an 18-wheel semi to transport 80,000 pounds in gross weight to deliver 2,000 pounds of cargo? How practical would it be if the truck could be used only once, or ten times, or a hundred times? This is the situation for all space flight, and it will not change while these propellants are used.

Alternative propellants that possess a thousand times the energy content of chemical propellants are possible, although they involve nuclear reactions. Unfortunately, any possibility of nuclear testing is crushed by an avalanche of red tape; this is the real problem. **DANIEL SCHAEFER,** BELBROOK, OHIO

New shuttle needed

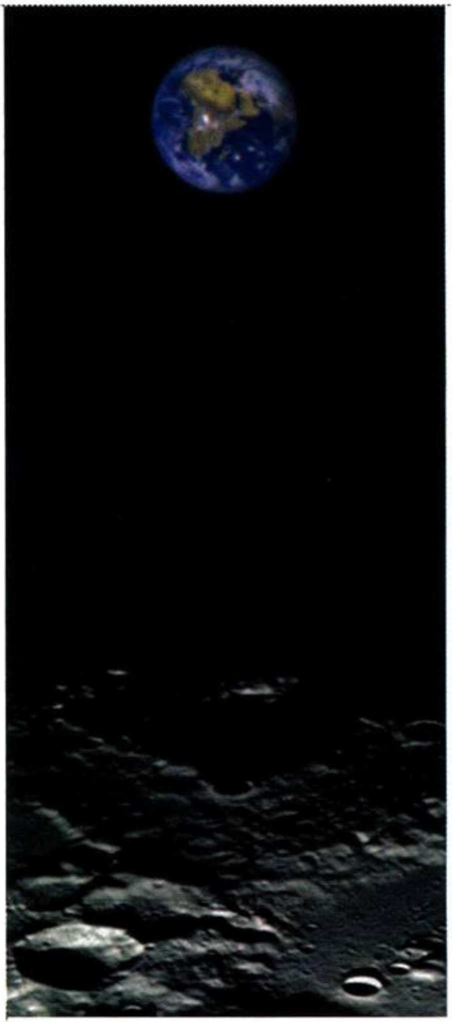
"What could be worth the price of a space shuttle crew?" by James Oberg (May 2003) sought to defend the space shuttle program, but an objective analysis indicates the program should be ended.

The concept was to fly a reliable, inexpensive, reusable vehicle. In fact, the shuttle rarely keeps to its launch schedule, is the most expensive launch vehicle, and requires so much maintenance that "reusable" is self-defeating.

We need to face reality. Two vehicles have been lost during missions at a cost of 14 lives and hundreds of millions of dollars in destroyed equipment, wreckage recovery, and investigations. The current shuttles should not fly again.

NASA put men on the Moon less than nine years after the goal was set; why, after twenty years, hasn't NASA updated the space shuttle with a newer model? **DAVID ALLEN HINES,** KINGSTON, PENNSYLVANIA

Nature's number



EARTH appears tantalizingly close to the Moon in this image from the Clementine spacecraft.

NRL/DOD/NASA

I would like to thank Mario Livio ("Searching for the golden ratio," April 2003) for shedding light on the amazing recurrence of a particular number (Φ), which governs physical phenomena on a scale from the microscopic to the astronomical. Who would have expected, for example, the shape of a spiral galaxy could be determined by the ratio of just two numbers? Previously unaware of such an association, I must confess this revelation came as quite a surprise to me. **HERMAN NACINOVICH,** GULGONG, NEW SOUTH WALES, AUSTRALIA

We welcome your comments. Send letters to Astronomy Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.

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BY BOB BERMAN

"F" in Science

Most astronomy lectures end with a Q & A session. If the audience seems shy or hesitant, I try to start the ball rolling by saying, "Go ahead, there's no such thing as a stupid question." But it's a lie. There are stupid questions. Here are my favorite dumb astronomy inquiries, all from adults, presented not to ridicule anyone (I'm lying again) but to illustrate the failure of our schools to impart the nature of the universe, everyone's real home. Almost every *Astronomy* reader has been periodically surprised by naïve comments or questions from friends or acquaintances, the type that amaze all of us with how little the general public knows about sky science.

This first one happened after an audience had viewed the newer IMAX version of "Powers of Ten." It's an animated trip outward from Earth that appears to travel 14 billion light-years to finally pause among clusters of galaxies at the edge of the visible universe. A gentleman asked:

"How did they retrieve the spacecraft that filmed all that, so that we get to see this movie?"

Being unaware that our space probes have never ventured to the nearest stars let alone to distant galaxies, coupled with ignorance of the universe's size, permits many similar misconceptions.

Next example comes from a woman who's apparently one of the 30% of Americans who believe we're being visited by aliens (some regard Roswell with near-religious awe as a sort of ET Mecca): "If a flying saucer didn't crash at Roswell, why won't the government release the information? Why won't they show us photos to prove there were no aliens there?"

She wanted to see a photo of no aliens!

Here's another, from just earlier this year: "You said the Sun is gas? I always thought the Sun was solid. How can a big ball like the Sun not be solid?"

Like many, this man in his sixties had trouble thinking of gas as real and substantial. Some also find it odd that gas can form itself into a ball. You can't really blame them. When you think about it, an enormous globe of brilliant, incandescent vapor moving across our sky each day is pretty amazing, even if we're used to it.

The next example isn't so much a single question but an entire category of paranoid queries. Each day we receive letters hinting at countless suspected conspiracies among space scientists and government officials. Some of the most popular: how the planets are about to line up and cause Armageddon; the secret hidden planet astronomers won't tell the public about; the asteroid or comet that's about to destroy Earth. Entire web sites are dedicated to these things, and they alarm an amazing number of the gullible and the goofy among us.

Here's the all-time winner. I know this may be hard to believe, but it's cross-my-heart true. Visiting us here in dark-sky country, my mother-in-law had gone out to get something from her car. When she walked back in, she asked, "What are all those little bright things in the sky?"

Not sure how to say it tactfully, my wife paused before replying, "Those are called stars, Mom."

We who love the sky assume our society has at least a basic science background. But it's a safe generalization that nearly everyone you know:

. . . Is aware of only a single astronomy number: nine planets. Some can also recite the distance to the Sun in miles: 93 million. Nobody can quote any other celestial figure or quantity, the distance to the nearest star, the diameters of the Moon or Sun, Earth's speed through space, nothing.

. . . Is familiar with exactly two star patterns, and neither is a full constellation. Big Dipper and Orion's belt. That's it.

. . . Cannot name an astronomical instrument or technique other than "telescope." Mention spectroscope and you might as well be saying Glurkoscope.

. . . Cannot identify *any* star in the sky.

. . . Believes a telescope's value is determined by its "power" or magnification.

. . . Cannot name a single crater on the Moon, nor a moon of any other planet, nor any asteroid.

. . . When asked about martian features, will say "canals."

. . . Has no idea what anything's made of. They'd be unlikely to guess that Saturn's rings are chunks of ice, the Sun is mostly hydrogen, or be able to name any of the most abundant elements of Earth's crust (oxygen, silicon, and aluminum).

Almost nobody has heard of an AU, knows that planets travel in elliptical orbits, can explain "solstice," is aware that stars rise earlier each night, has any idea what the ecliptic is, or that the Moon and Sun move rightward across the sky. They don't know why the Sun shines or why the sky is blue.

We walk among crowds in malls and stand in elevators with other people. But when it comes to astronomy, we backyard sky enthusiasts are as separate from them as drifting asteroids. Kudos to those amateurs who set up telescopes, encourage neighbors, lecture at schools, and shed light on a growing awareness.

But in the meantime, please send in the dumbest question you've ever been asked. Let's see if we can find competition for "What are all those bright things in the sky?" *We'll make it a contest. Offer void on* Uranus. Wherever that is.

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BY GLENN CHAPLE

Beginner's luck

Chances are, you read this column because you recently became interested in astronomy and want to know more about the night sky. Perhaps you aspire to someday join the ranks of the so-called "serious" amateur astronomers. Ah yes, you'll be one of those star-savvy veterans who use high-tech equipment to take stunning astrophotos like the ones inside this magazine. Maybe you'll collect important data — timing the occultation of a star by a passing asteroid or diligently recording the magnitudes of variable stars. Too bad you're just a beginner, unable to enjoy the pleasures of "real" astronomy.

But wait! As a beginner, you're at one of the most enjoyable stages of amateur astronomy. Each evening promises some exotic adventure — the sighting of a constellation you've never seen before, or a first-time telescopic view of Saturn or the Orion Nebula. The night sky is a playground to explore, not a lab filled with specimens to dissect and analyze.

I'm not knocking "serious" astronomy. Each clear night, I spend an hour or so studying the goings-on of variable stars — stars that, for a variety of reasons, undergo changes in brightness. I find the work (if you can call it "work") to be rewarding. But now and then I get so wrapped up in observing that I fail to just soak in the beauty and magnitude of it all. We all need to pause and "smell the roses" — something the novice is more inclined to do than the veteran.

So this month we take a vacation from meteor showers, eclipses, and planetary oppositions (well, you might want to put in a little time on Mars — this is a very favorable opposition, after all) and take a river cruise — Milky Way style. We'll travel light — a lawn chair, binoculars, and (as an option) a small telescope.

THE MILKY WAY GALAXY offers countless exotic observing objects for beginners and veterans alike. GIANNI TUMINO AND MELANIA PLUCHINOTTA

The Milky Way is that misty band of light you see arching across the sky on a late summer/early autumn evening. Best seen from a rural area (the farther from city lights, the better) on a clear, moonless night, the Milky Way passes from Cassiopeia the Queen in the north, through Cygnus the Swan, and southward to Sagittarius. As you face Sagittarius the Archer, you're looking into the very heart of the Milky Way.

Once you find a dark site, position your lawn chair so you can lie back and see as much of the Milky Way as possible. Before taking out your binoculars, scan the length of the Milky Way, beginning at Cassiopeia. If you're not sure where in the sky to look, use the all-sky map on page 69 as a guide. From Cygnus southward, you'll see an occasional rift in the Milky Way, a dark lane caused by obscuring dust. Notice how much richer the Milky Way appears the farther south you go.

Now that you've scouted the area it's time to take out your binoculars and begin your "cruise." Your port of departure is Cassiopeia. The minute you peer into your binoculars, you'll be dazzled by the numerous stellar specks you see. This is the sight that amazed Galileo when, nearly four centuries ago, he became the first human to view the Milky Way with a telescope. Leisurely drift southward, looking away from your binoculars only long enough to stay on course. You may stumble upon an open star cluster, globular star cluster, or even a nebula tucked away amid the myriad background stars. Don't get up and check an atlas to identify anything. You're on vacation, remember? You can explore and even sketch these deep-space wonders later. For now, enjoy!

Delight in the scenery on this "river in the sky." The slower you go, the more you'll see. When you arrive at the southern horizon, you can return to Cassiopeia and start again. Your next cruise might well reveal new sights and wonders.

If you own a telescope, you may be tempted to turn it loose on the Milky Way. Viewing the Milky Way with a high-power telescope is like studying the Mississippi River with a microscope. You'll get a close-up view, but only one cosmic drop at a time. If you must use a telescope, I suggest that it be a low-power "rich-field" telescope like Edmund Scientific's Astroscan or Bushnell's Voyager. A "rich-field" telescope fits the gap between binoculars and more traditional high-power scopes. Its spectacular wide field is ideal for Milky Way viewing.

When people ask astronomers what sky sight inspires them most, some will immediately mention Saturn and its rings. A few will describe in wide-eyed detail the Moon and its spectacular cratered surface. Others will pick something more exotic — the Orion Nebula, the Pleiades star cluster, or the Andromeda Galaxy. But to me, no cosmic scene is as incredible as the summer Milky Way viewed with the unaided eye.

NEXT MONTH: In the spirit of football season, we "go deep." Clear skies!

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BY WILLIAM SCHOMAKER

Seth Shostak

From the remote outpost of a rocky planet caught in the thick of a cosmic bottleneck of 100 billion stars swirling about the center of the Milky Way, Seth Shostak patiently waits and listens for someone with something intelligent to say. But Shostak isn't looking for just any someone. He and his Project Phoenix cohorts at the Search for Extraterrestrial Intelligence (SETI) Institute in Mountain View, California, are on the hunt for aliens. I recently caught up with Shostak at the Arecibo radio telescope in Puerto Rico as he scoured the sky, star by star, for signs of life beyond Earth.

Is it likely SETI could be scooped?

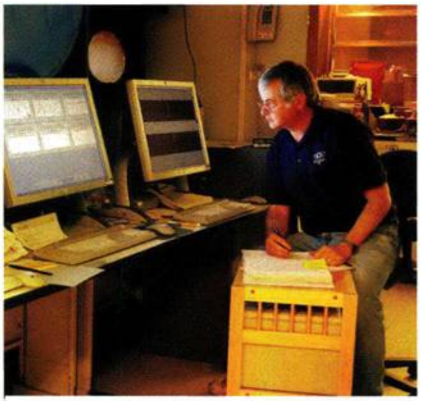
When you consider the history of major discovery, it's often the case that new knowledge comes from unexpected quarters. So of course it's possible that our first conclusive proof of the existence of intelligence beyond Earth may originate with an amateur, or possibly even the military.

But I still think that our SETI efforts have the best chance. The SETI Institute is much like the National Cancer Institute — a focused research effort that seeks to maximize the chances of success. The cure for cancer might come out of some non-NCI lab, or even out of research that has nothing to do with cancer. If you had to *bet* who's going to beat this disease, though, the Institute would definitely have short odds.

Is a gambling spirit a prerequisite for doing what you do?

I would be disingenuous if I claimed not to have a certain penchant for "gambling." After all, it's hard to turn a dollar into the price of a German car anywhere but Las Vegas or the local lottery outlet.

But actually, I think that my personal situation lies near the middle of the confidence spectrum, somewhere between conservative and cocksure.



SETH SHOSTAK, in Arecibo Observatory's control room, patiently waits for E.T. to phone Earth. SETH SHOSTAK

Yes, I think they're out there. Is it only a question of time until we trip across them? I firmly believe the answer to that is "yes." The problematic query is, "when?"

Suppose you hit pay dirt with the next target. Then what?

We have a protocol for actions following the detection of a signal. We would first check out the signal — to be sure it's actually extraterrestrial, and not earthly interference or even a prank — and then alert the astronomical community, the government, and the public.

Many folks assume there's some sort of governmental concern about the detection of an alien signal, but I've never seen such evidence. Earth has probably been pelted by signals from throughout the Milky Way since its birth. Now, suddenly, 4.6 billion years into our planet's history, we're able to detect those signals, and maybe we will. There won't be any secreting away the evidence in southern Nevada or some similar, remote locale. The evidence would be accessible to anyone with a large telescope.

If Earth really is bombarded with ET-chatter, could "intelligent noise" hinder future radio investigation of the universe?

From my point of view, it would be an embarrassment of riches if the galaxy were chock-a-block with intelligent noise. But we've not yet been impeded in our study of the universe because of interference from other civilizations, and I seriously doubt that we ever will — unless, of course, the extraterrestrials are operating on a scale so vast that they've actually *defined* our view of the universe!

In trying political, economic, and social times like these, do you feel the search for ET matters more or matters less?

Arguments against esoteric research could have been made at any time in history. Perhaps we could have turned Galileo to the task of helping the downtrodden of Venice. But it was undoubtedly better for society in the long run that Galileo applied his talents elsewhere — to discovery and understanding. Our SETI situation is a bit like Galileo's, too, in that the technology of the early 17th century finally allowed the construction of a telescope that would be useful for astronomy. Now, in the first part of the 21st century, we finally have the tools to reveal the presence of cosmic brethren. Research is simply formalized curiosity. And curiosity — the impulse to know — is one of the few things that distinguish us from the million other species that creep and crawl across Earth. ■

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Quick Facts About Mars This August

***Closest Approach:** Morning of August 27 at 5:51 a.m. Eastern Daylight Time*

***How Close?** Measured from the center of the Earth to the center of Mars = 34,646,418 miles*

***How long has it been since it was this close?** Almost 60,000 years ago. Actual date: 57,617 B.C.*

***When will Mars be this close again?** August, 2287*

***How big is it going to get?** 25.11 arc seconds maximum (6x larger than usual)*

***How bright?** Mag –2.9*

***Perihelion** (closest to Sun): August 29th*

***Opposition:** August 28th at 18 UT*

***Which constellation is Mars going to be in during maximum?** Aquarius*

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NASA'S AQUA SATELLITE combines visible, infrared, and microwave measurements of the atmosphere to create three-dimensional models of the weather as viewed from space. These data should add accuracy to weather forecasts.

news 09

Read all about it: Hubble shoots the Helix, high-speed gas shapes nebula, Mars rovers fly away, and 30 years of planetary exploration.

EXTRAGALACTIC ASTRONOMY

Violence begets new light

The active galaxy Perseus A (NGC 1275) lies at the center of the Perseus Cluster. In most ground-based images, this brightest cluster galaxy looks like a regular giant elliptical. But a more complicated and violent picture emerges when astronomers look closer, using either adaptive optics or the Hubble Space Telescope.

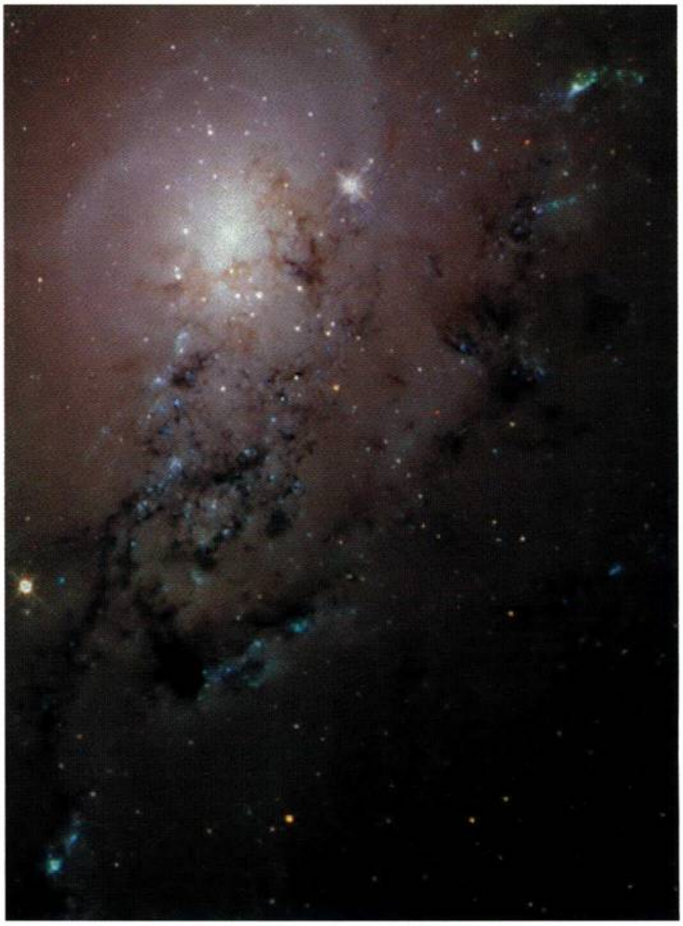
This Hubble Heritage image reveals rich dust lanes littered with blue pockets of star formation that delineate a kamikaze spiral galaxy crashing into Perseus A. This spiral is viewed nearly edge-on.

The collision of this spiral with Perseus A follows on the heels of an earlier merger of the elliptical with a smaller system. That merger, occurring just tens of millions of years ago, created ripples around Perseus A and caused globular clusters to form.

In both cases, the shocks from collisions triggered star formation. Simultaneously, the mergers disrupted the systems' structures. Over time, the ripples will settle and star formation will end, leaving Perseus A as a typical, smooth giant elliptical galaxy.

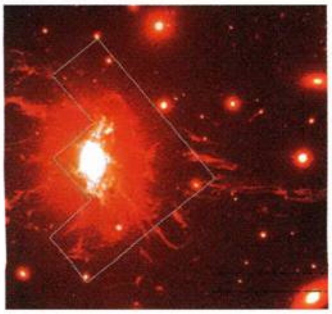
Filaments of gas surrounding Perseus A, however, may not disappear. Similar in morphology to filaments in the Crab Nebula, these loops of gas may be related to giant magnetic fields. In a 2001 paper, Caltech astronomer Christopher Conselice and his collaborators suggested that an interaction between gas in the Perseus cluster and plasma ejected from Perseus A's active nucleus produces the gas filaments. These filaments may be constantly reforming.

— PAMELA L. GAY



COLLISIONS ROCK THE HEART of the Perseus Cluster as a spiral galaxy falls edge-on into the cluster's central galaxy, Perseus A.

NASA/THE HUBBLE HERITAGE TEAM (STScI/AURA)/ M. DONAHUE (STScI)/J. TRAUGER (JPL)



FILAMENTS TWIST AND LOOP around Perseus A. Star clusters form at some filament junctures.

C. CONSELICE (CALTECH)

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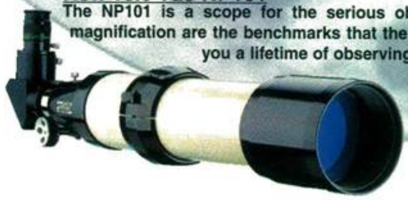

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SCIENTISTS

Debating origins

In April 2003, Jesuit priest and astronomer Father George Coyne and Nobel laureate physicist Steven Weinberg publicly debated "The universe and the presence of God" before a record-setting audience at the Houston Museum of Natural Science. The issue: whether the universe was intelligently designed or simply came to be.

CASTEL GANDOLFO mixes science and religion at the papal summer residence outside Rome. MASSIMO CIRILLI /VATICAN OBSERVATORY

The debate was not a typical "creationism versus evolution" argument. Instead, it was an outgrowth of a larger dialogue on the development of astronomer-priests, from sky-priests at Stonehenge to astrophysicist-priests at the Vatican Observatory today.

Coyne presented a thought-provoking discourse on the evolution of the universe from the Big Bang to humans. The increased complexity he outlined seemed to imply universal destiny, with everything evolving toward a set end, but he surprised the audience by declaring that a universe seemingly working its way to greater self-reflection is not proof of God's existence. He did add, however, that increased understanding of the universe's evolution increases his knowledge about the god in which he believes.

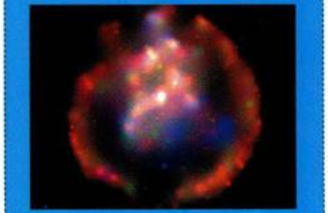
Weinberg suggested that if the universe can operate without a deity, there is little point in muddying the waters with the concept of one. As science progresses, Weinberg asserted, it would provide alternative explanations for more phenomena. Such replacement of divine intervention by scientific understanding has occurred throughout history. Furthermore, given the physical and moral evils in society, Weinberg doubts that any god ever intervened in human lives.

This eternal debate might have metamorphosed throughout history, but the tension between science and religion remains a constant. — **C. RENÉE JAMES**

SUPERNOVAE

Rings in space

The Chandra X-ray Observatory caught on camera the first-ever images of oxygen and other elements being dispersed in a supernova remnant. The detection of these heavy atoms confirmed astronomers' suspicions that massive stars produce these elements.



A SHOCKWAVE RING surrounds SNR 0103–72.6. NASA/CXC/PENN STATE/S. PARK ET AL.

Chandra imaged a near-perfect ring surrounding a cloud of heavy elements in supernova remnant SNR 0103–72.6. Shockwaves produced by ejected material striking the interstellar gas created the ring, which has been expanding for about 10,000 years. Sangwook Park of Penn State announced these findings in May 2003. — P. L. G.

HUBBLE IMAGES

Lucky Helix placement

The Hubble Space Telescope [HST] produced one of the largest and most detailed images ever made of the Helix Nebula [NGC 7293] for Astronomy Day 2003.

During the 2002 Leonid meteor storm, controllers turned the HST's tail toward the meteor stream to protect the telescope's delicate instruments from debris. Coincidentally, this placed the Helix Nebula in Hubble's field of view. While it weathered out the storm, the HST imaged the Helix Nebula for nine orbits.

Scientists assembled nine HST images into a mosaic of the nebula's core. A wide-field image from the 0.9-meter telescope at Kitt Peak Observatory in Arizona filled out the rest of the nebula.

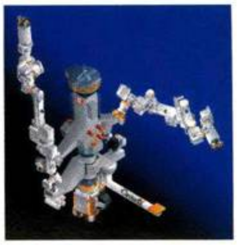
FILAMENTS DANCE in the Helix Nebula. NASA/ESA/NOAO/ HUBBLE HELIX NEBULA TEAM/ M. MEIXNER [STScI]/T. A. RECTOR [NRAO]

The resulting picture shows extraordinary details, including filaments of matter aligned radially along the inner rim of the nebula's bright ring. Astronomers believe these bright filaments result from hot stellar gas colliding with colder shells of dust and gas previously ejected from the nebula's central star. — **MATT DUNN**

INTERNATIONAL SPACE STATION

Canada lends an arm

Dextre, the Special Purpose Dexterous Manipulator, is a sophisticated, relocatable, two-armed robot undergoing final testing at MDRobotics outside of Toronto.



WITH GRIPPING HANDS, Dextre's arms manipulate payload and tools. CSA

Unveiling Dextre at a naming ceremony in April 2003, Canadian Space Agency president Marc Garneau affirmed that this technology would help future International Space Station (ISS) crews perform intricate construction and maintenance tasks. Dextre will service small components on the ISS exterior. This alleviates the need for demanding and dangerous spacewalks.

Dextre comes fully equipped with lights, video equipment, and a tool platform. Its robotic hands are even delicate enough to pop a videotape out of a VCR.

Dextre is the third and last element in Canada's contribution to the ISS's robotic mobile servicing platform that already includes the agile Canadarm2. Dextre is slated for a 2005 shuttle launch.

— **ANDREW FAZEKAS**

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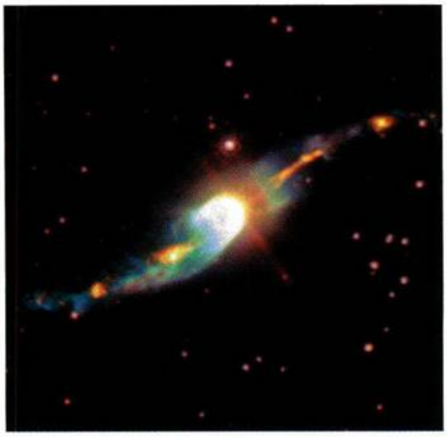
HUBBLE IMAGE

Gas at high speed

Bizarre, S-shaped gas jets emerging from Heinze 3–1475 earned the young planetary nebula a nickname: "The Garden Sprinkler Nebula."



MYSTERIOUS, HIGH-SPEED GAS JETS emerge from Heinze 3–1475, a young planetary nebula located in the constellation Sagittarius. ESA, A. RIERA (UNIVERSITAT POLITÈCNICA DE CATALUNYA), AND P. GARCÍA-LARIO (ESA)

Long outflows of fast-moving gas, or "jets," are found near a variety of objects in the universe, including young stars, neutron stars, black holes, and planetary nebulae. Astronomers believe these jets may originate in tiny, currently unobservable regions of space. Like water from a sprinkler in a suburban backyard, these gas jets stream from "nozzles" that produce twin sprays. Dust particles that keep astronomers from seeing into planetary nebulae centers also hide the nozzles.

Located 18,000 light-years from Earth in the constellation Sagittarius, Heinze 3–1475 hosts a central star that is more than 12,000 times the Sun's luminosity and is three to five times more massive.

The nebula boasts the fastest jets ever recorded, with velocities of approximately 4 million kilometers per hour. The jets' flow is intermittent, ejecting gas about every 100 years. This episodic spray isn't well understood; astronomers think either the magnetic cycle of the nebula's central star or interactions with a companion star could trigger this behavior. — **LAURA WILLIAMS**

Time won't be quantized

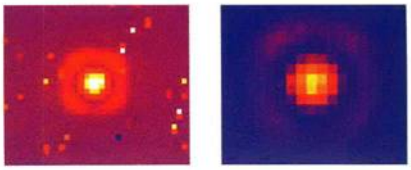
Throughout the last century, theorists sought to unify general relativity with quantum mechanics. While they fell short of establishing a complete theory, they did define what a quantum-gravity theory should include. One testable aspect of their theory was quantized time. Now, however, it appears that time has failed the quantum test.

Quantum mechanics says all things — energy, momentum, position, size, time — can be broken into small pieces called "quanta," which can't be broken down further. If quantized, time should have a minimum unit called a "Planck time" (named after the German physicist Max Planck who originated the idea of quanta), which equals 10^{-43} second. This implies that life, like a movie, may appear to be a continuum of events but is really a series of snapshots that together define the past, present, and future.

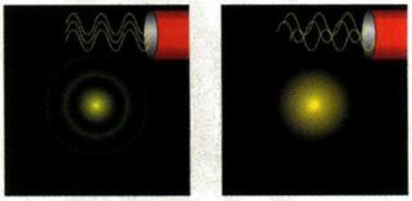
If true, then measurements smaller than a Planck time are impossible. Just as you can't precisely measure the size of an atom with a yardstick, you can't measure time with absolute precision using Planck time.

Observationally, this has consequences. The speed of light can't be defined to a precision better than one Planck time. This allows photons to have minute speed differences.

These minute differences matter. Specifically, photons emitted from an object move out of phase as some pull ahead and others fall behind, and their wavelengths no longer sync up. Over short distances, phase discrepancies are unnoticeable, just as the difference between cars going 90 and 92 miles per hour isn't evident after they've traveled 100 feet. Over large distances, differences in phase become apparent, just as the speed difference between the cars is obvious after 1,000 miles.



AIRY DISKS SURROUND DISTANT GALAXIES PKS 1413+135 (left) and PKS 1557+032 (right) HST/E. S. PERLMAN ET AL.



PHASED LIGHT CREATES AIRY DISKS (left) while light out of phase (right) creates slightly blurred images. PAMELA L. GAY

If photons are in phase, their light waves produce a faint ring of light called an "Airy disk" around the image of a luminous object like a star. If their speeds have variations smaller than a Planck time, photons will move out of phase over large distances and an object's Airy disk will be blurred.

So, if time is quantized, images of distant objects shouldn't have Airy disks around them.

But they do.

In independent studies, Richard Lieu and Lloyd Hillman of the University of Alabama and a team led by Roberto Ragazzoni of Germany's Max Planck Institute used Hubble Space Telescope images to show that Airy disks surround distant galaxies. Their conclusion: Time isn't quantized.

This poses a large problem for theorists. According to Lieu, "The Big Bang theory supposes that at the instant of creation, the quantum singularity that became the universe would need to have infinite density and temperature. To avoid that sticky problem, theorists invoked the Planck time. They said if the instant of creation was also a quantum event, when space and time were both blurry, then you don't need infinite density and temperature at the start of the Big Bang."

Without quantum time, the universe becomes mathematically uglier at the moment of its inception. For now, a unified theory of relativity and quantum mechanics remains elusive. — **P. L. G.**

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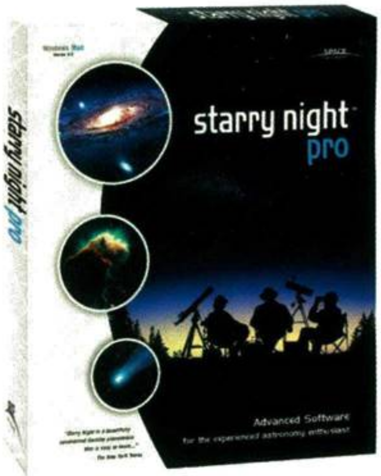

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PLANETARY SCIENCE

Mars Rovers away

NASA and ESA both have launched missions to Mars to better understand the geology of the Red Planet and to possibly discover evidence of life there.

ESA's Mars Express mission was launched June 2, 2003, from the Baikonur Cosmodrome in Kazakhstan. After a courtesy orbit around Earth, the orbiter's rockets fired it on an interplanetary trajectory. The May 23 launch was delayed so engineers could repair a malfunction in an electronics module. Early telemetry shows Mars Express functioning perfectly.

MARS EXPRESS launched from Baikonur Cosmodrome on June 2, 2003 (left). ESA **THE MARS EXPLORATION ROVER SPIRIT** launched from Cape Canaveral on June 10, 2003 (right). NASA

Mars Express consists of a small orbiter and a lander. The orbiter's instruments search for subsurface water and collect information about a host of other environmental factors. The lander, Beagle 2, will provide surface imagery and analysis of soils and rocks. Its instrument platform acquires data with a robotic arm that grinds and cores rocks. The arm also deploys a burrowing device to retrieve soil samples.

NASA launched Spirit, the first of two Mars Exploration Rovers, on June 10. After a perfect Cape Canaveral launch, the rocket headed into interplanetary space. Next stop — Mars. This rover carries its instrumentation on board and has a considerably longer traveling range than earlier rovers. Its robotic arm contains a microscope, spectrometers, and a rock abrasion tool to study the historical climate and possible presence of surface water at its landing site.

Beagle 2 is slated to land on Christmas 2003. Mars Express should arrive in martian orbit on December 26, 2003, and the Mars Exploration Rover will land more than a week later, on January 3, 2004. — **M. D.**

AWARD WINNER

Excellence

The Astronomical Society of the Pacific (ASP) awarded Kyle Smalley, 41, the 2003 Amateur Achievement Award for his 2002 asteroid research.

Smalley became interested in the hobby of astronomy just eight years ago. Professionally employed as a computer programmer, Smalley joined the Astronomical Society of Kansas City. As a member, he observed asteroids from dusk 'til dawn at a site near Louisburg, Kansas, with the club's homebuilt 30-inch Newtonian. Using a camera supplied by a NASA grant, Smalley recorded hundreds of asteroid images nightly, sometimes imaging up to twenty asteroids per run.

This award can be considered a diploma for his recent graduation from a hobbyist to a professional astronomer; Harvard's Center for Astrophysics appointed Smalley as a consultant to the Minor Planet Center at the beginning of 2003. This culminates a brief — astronomically speaking — yet productive stint as an amateur astronomer. — MATT QUANDT

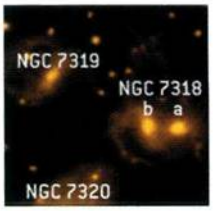
EXTRAGALACTIC ASTRONOMY

Rated X due to x-ray emission: Stephan's Quintet

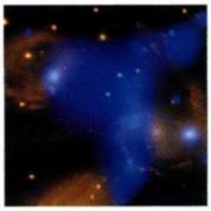
Gas that is invisible in optical light images of Stephan's Quintet (NGC 7317–7320) glows prominently in x-ray observations. New images taken with NASA's Chandra X-ray Observatory show a wall of high temperature gas running through the heart of this nearby compact galaxy group.

The spiral galaxy NGC 7318b shock-heated the gas to 6 million degrees Celsius, causing it to emit x rays. This galaxy passes rapidly through the group, heating gas as it goes. Past intruders, such as NGC 7320c, may have triggered the faint x-ray emission visible throughout the group.

Ginevra Trinchieri of the INAF-Brera Observatory in Milan led this work. NGC 7320 is a foreground galaxy. — **P. L. G.**



OPTICAL GALAXIES define Stephan's Quintet. PAL. OBS. DSS



X-RAY GAS GLOWS in this galaxy group. NASA/CXC/INAF-BRERA/G. TRINCHIERI ET AL.

SOLAR SYSTEM

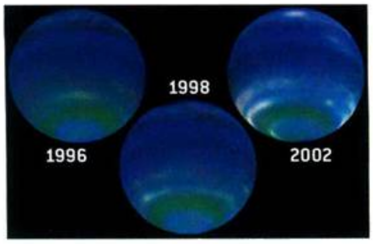
Neptune's signs of spring

Could spring bring warmth to a planet 2.8 billion miles from the Sun? Hubble Space Telescope observations of Neptune suggest it can. Images show growing and brightening clouds in the planet's southern hemisphere.

Just as Earth's 23.5° axial tilt creates our seasons, Neptune's 29° lean allows extra sunlight to warm its southern hemisphere, creating spring on Neptune.

"We'd expect heating in the hemisphere getting the most sunlight," says lead researcher Lawrence Sromovsky of the University of Wisconsin. "This in turn could force rising motions, condensation, and increased cloud cover."

The clouds have been brightening since 1980. If billowing clouds are a sign of spring, the trend will continue for another twenty years. Neptune's orbital period is so long (164.8 years) that each season lasts four decades. — **VANESSA THOMAS**



GROWING CLOUDS mark the passage of spring during Neptune's 164.8-year orbit. NASA/L. SROMOVSKY AND P. FRY (UNIV. WISCONSIN)

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- Autoguider port for long exposure astrophotography
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- DC Servo motors with encoders on both axes
- *The CG-5 GT computerized mount* features Celestron's sleek integrated design.

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C9¼-S #11045 Non-Computerized
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We are proud to offer the GT versions of the Advanced Series on a computerized **GoTo** version of Celestron's sturdy CG-5 mount. Couple this solid mount with the included computerized control system to utilize many of the same functions and features, like the **NexStar computer control system** and an **Autoguider port** for long exposure deep sky astrophotography, as Celestron's most advanced GoTo telescopes. **GoTo models are also upgradeable to GPS** with the optional **CN16 GPS Accessory (#93963)** allowing your telescope to pinpoint your position on the earth, the date and time, and making the alignment process faster and easier than ever before! These GoTo versions of the Advanced Series also come loaded with new software features and **over 40,000 database objects**. Capable of holding over 35 lbs of payload and slewing at 4° per second, you will be able to instantly point to any of the celestial objects in the database.

Specifications — All Advanced Series Telescopes

	21016 C4-R	11071/11072 C5-S	31056 C6-N	21019/21020 C6-R	11025/11024 C8-S	31061/31062 C8-N	11045/11046 C9 1/4-S	11047/11048 C10-N
Optical Design	102mm (4.0") refractor	127mm(5") Schmidt-Cassegrain	150mm (6.0") reflector	150mm (6.0") refractor	203mm (8") Schmidt-Cassegrain	200mm (8.0") reflector	235mm (9.25") Schmidt-Cassegrain	254mm (10") reflector
Focal Length	1000mm f/10	1250mm f/10	750mm f/5	1200mm f/8	2032mm f/10	1000mm f/5	2350mm f/10	1200mm f/4.7
Finderscope	6x30	6x30	6x30	9x50	6x30	9x50	6x30	9x50
Mount	CG-4 Equatorial	CG-5 Equatorial	CG-4 Equatorial	CG-5 Equatorial	CG-5 Equatorial	CG-5 Equatorial	CG-5 Equatorial	CG-5 Equatorial
Eyepiece	1-1/4" – 20mm (50x)	1-1/4" – 25mm (50x)	1-1/4" – 20mm (38x)	1-1/4" – 20mm (60x)	1-1/4" – 25mm (81x)	1-1/4" – 20mm (50x)	1-1/4" – 25mm (94x)	1-1/4" – 20mm (60x)
Star Diagonal	1-1/4"	1-1/4"	n/a	1-1/4"	1-1/4"	n/a	1-1/4"	n/a
Accessory tray	yes	yes	yes	yes	yes	yes	yes	yes
Tripod	Aluminum	2" Stainless Steel	Aluminum	2" Stainless Steel	2" Stainless Steel	2" Stainless Steel	2" Stainless Steel	2" Stainless Steel
CD ROM	The Sky Level 1	The Sky Level 1	The Sky Level 1	The Sky Level 1	The Sky Level 1	The Sky Level 1	The Sky Level 1	The Sky L1

Additional Specifications — Computerized Models

Hand Control	Double line, 16 character Crystal Display; 19 fiber optic backlit LED buttons
Motor: Type	DC Servo motors with encoders, both axes
Max Slew Speed	4°/second
Software Precision	24bit, 0.08 arcsec calculation
Hand Control Ports	RS-232 communication port on hand control
Motor Ports	Aux Port, Autoguide Ports
Tracking Rates	Sidereal, Solar and Lunar
Tracking Modes	EQ North & EQ South
Alignment Procedures	AutoAlign, 2-Star Alignment, Quick Align
Database	40,000+ objects, 400 user defined programmable objects

C4-R #21016
$ 399 + $40 S&H

C5-SGT
[11072]

C5-SGT #11072 (shown)
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C5-S #11071
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C6-N #31056
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C8-SGT
[11026]

C8-SGT #11026 (shown)
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C8-NGT
[31062]

C8-NGT #31062 (shown)
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C8-N [31061]
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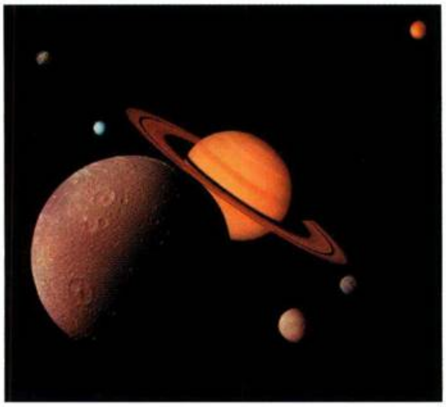
RETROSPECTIVE

Planets, ho!

For millennia, planets were intellectually unreachable dots. But men like Kepler and Galileo changed the dialogue from what planets did — wander the sky — to what they were — other worlds orbiting the Sun.

This change in perspective changed the questions asked about planets. People wanted to know what conditions were like on their surfaces. Did they have life? Could we travel there? For many generations, answers remained out of reach.

Then, technology brought answers. In the 1960s, NASA flew probes past Venus and Mars. And in the early 1970s, the first generation of landers opened a new phase of surface exploration.



UP-CLOSE PLANETARY VIEWS became possible thanks to space probes such as Voyagers I and II, Galileo, and Mars Global Surveyor. NASA/JPL

Planetary landers and orbiters created an entirely new field of study: planetary science. This sister-science to terrestrial geology uses images of other planets to answer questions concerning extraterrestrial mineralogy, climate, and plate tectonics. Planetary scientists also may look for life and fossilized life.

In the coming years, NASA probes will explore Mars, Saturn's moon Titan, Jupiter's moon Europa, and other surfaces in our Solar System. These robots may prepare the way for humans to walk on extraterrestrial worlds. One by one, questions of the past are being answered in the present. — **JAMES OBERG**

The orbital ties that bind: U.S.–Russian space relations

THE INTERNATIONAL SPACE STATION will help advance human on-orbit research and multi-national collaborations. NASA

In 1961, the Soviet Union launched Yuri Gagarin into space, and with his successful return to Earth, the international space race began. International cooperation was integral in many activities during the "Great Space Race" of the 1960s, but collaborations were mainly between partners in Europe, Canada, and Japan, and either of the chief contestants — the United States or the Soviet Union.

For the first decade or so of manned space flight, astronauts and cosmonauts ventured into space, completed tasks, and came home to Earth. But beginning in the early 1970s, space became their home, albeit a temporary one (weeks, then months). They lived on prototype space stations such as the Soviet Salyut-1 and the United States' Skylab.

By 1972, the "Moon Race" was over, and parallel U.S.–Soviet programs for space stations, as well as Mars probes and other big-ticket projects, appeared increasingly duplicative. So, as astronauts began to linger longer in space, the first tentative steps were taken for broader cooperation between the two global superpowers.

As with many large collaborations, the motivations of individual nations may have been questionable at first. They postured for prestige and flexed their technological muscles to show commercial and military advantage. Still, "progress" was in the right direction. And when the Soviet Union collapsed in 1991 and the Cold War ended, the space agencies had already prepared the engineering groundwork for more intimate international cooperation.

The construction of the International Space Station (ISS) is perhaps the greatest achievement of this new, international conquest of space.

Arriving at this point required a revolutionary change in perspective. In the ISS, astronauts would have time to gaze out windows and contemplate. They could relax on-orbit and restore their energies between major tasks. Space journeys were no longer just quick business trips filled with constant activity.

With astronauts and cosmonauts often living in space for half a year at a time, space missions were replaced with orbital "expeditions." Some trips lasted over a year, proving that humans can handle the physiological and psychological stresses that will accompany future interplanetary missions.

The International Space Station is only one among many flourishing international collaborations. The level of international cooperation today is fundamentally different — and probably better — than it was thirty years ago. Border-crossing commercial satellite launches, internationally designed and constructed interplanetary probes, and research collaborations are now standard practice. More nations also have launch abilities.

As motivations continue to change, and relationships between nations ebb and flow, there appears to be little chance of returning to a "space race" dominated by two contestants. — **J. O.**

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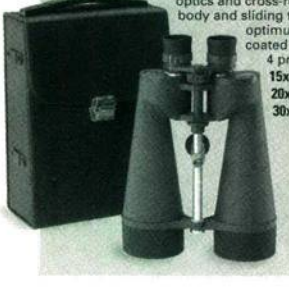

Premium giant binoculars with high-power optics and cross-reinforced aluminum body and sliding tripod mounting post for optimum balance. Fully multi-coated 80mm lenses with BAK-4 prisms. Long eye relief.

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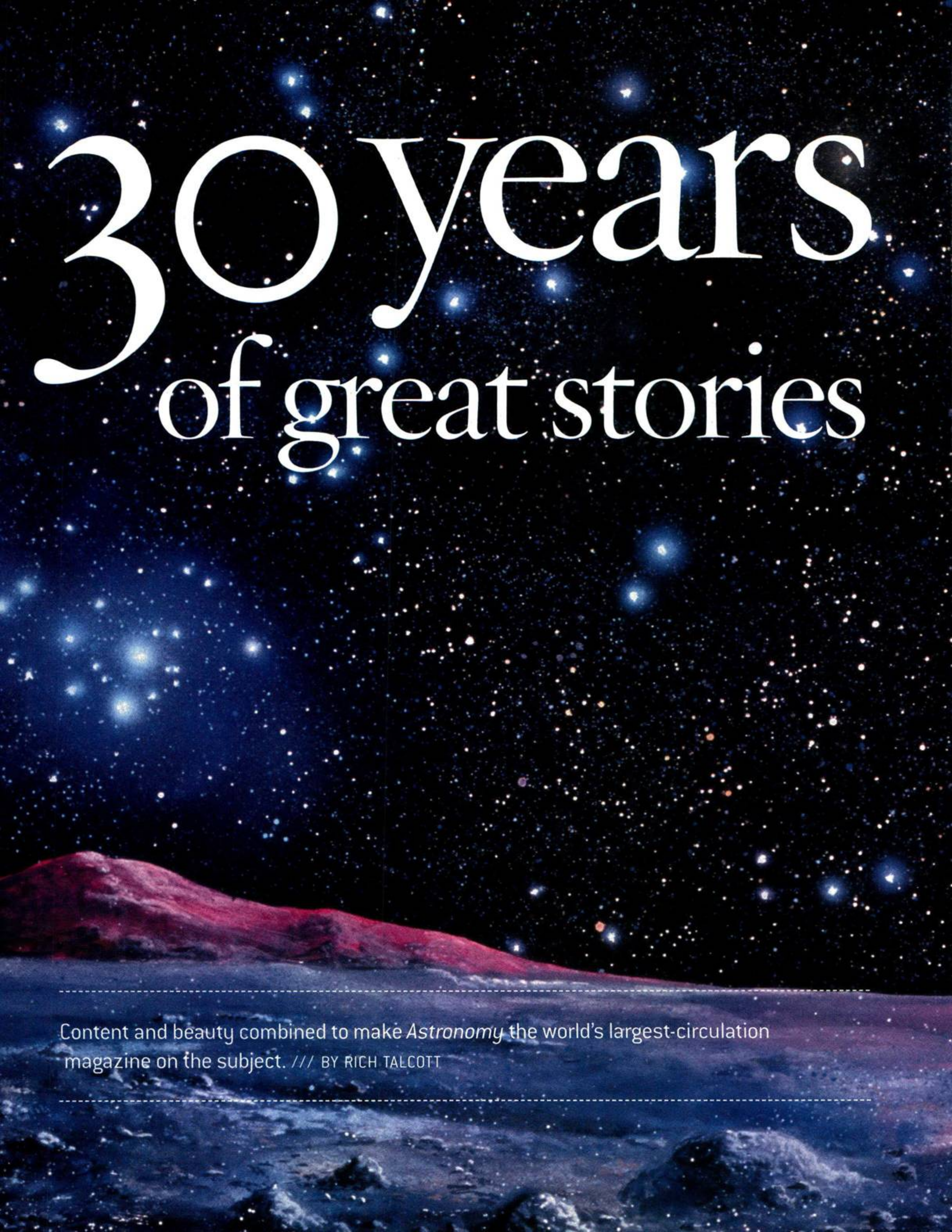
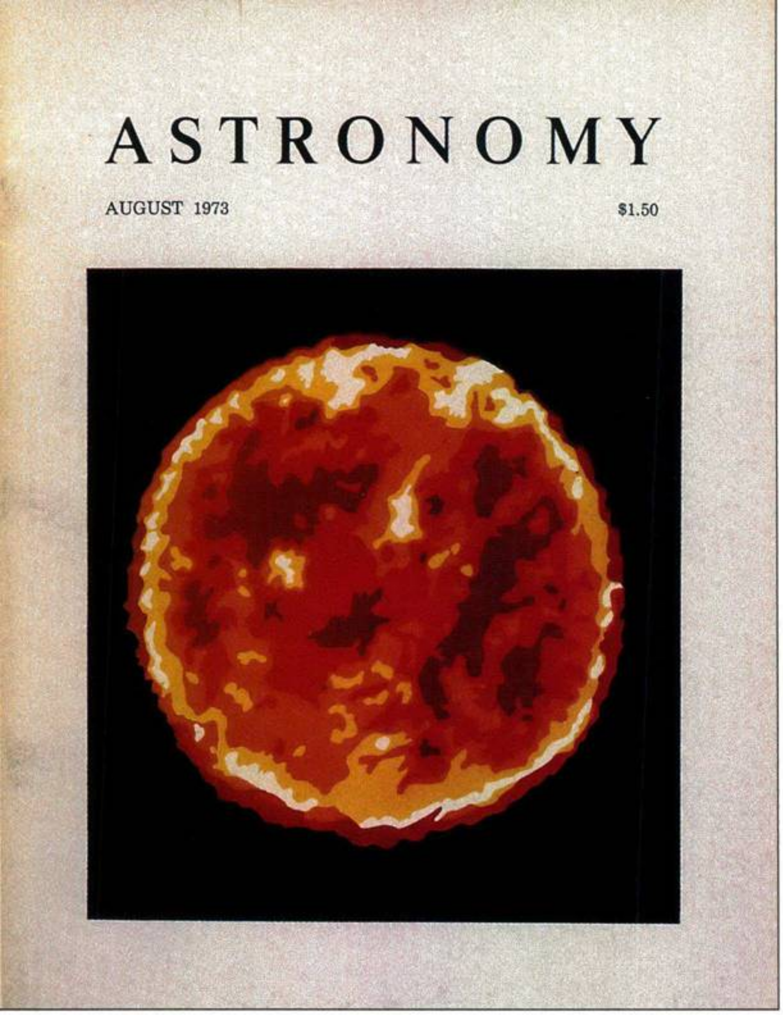
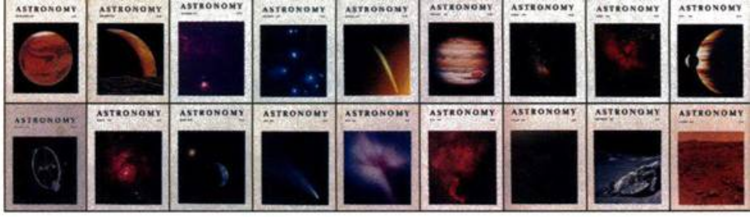


30 years of great stories

Content and beauty combined to make *Astronomy* the world's largest-circulation magazine on the subject. /// BY RICH TALCOTT

EXOTIC SPACE ART has always allowed *Astronomy* to take readers where no humans or spacecraft can go. PAINTING BY RICK STERNBACH





August 1973. To many people, it marked the end of an era. On August 17, baseball legend Willie Mays launched the 660th — and final — home run of his celebrated career into the night air of New York's Shea Stadium.

That same month, a small company in Milwaukee, Wisconsin, launched a 48-page journal with the temerity to call itself "The World's Most Beautiful Astronomy Magazine." Would this brash rookie have what it takes for a long, prosperous existence, or would it vanish quickly like most new publications? Thirty years later, *Astronomy* has proven the power of a simple idea.

Yet beauty takes you only so far in this world. Unless there's substance to back up the pretty photos and stunning artwork, the chances for success are slim.

The early years

From the beginning, *Astronomy* struck a balance between delivering the latest news from the science of astronomy and providing advice on how to observe the sky. The premier issue featured stories on the search for Planet X and the science behind solar eclipses, while observers learned about the month's sky events in "Sky Almanac" as well as how to view variable stars and the best deep-sky objects in Capricornus.

The big story of 1973 is one many of us would rather forget. The October issue featured "Kohoutek: Great Comet of the Century." Touting the approaching comet as perhaps the best since 1882, the magazine — and most everyone else — promised the show of a lifetime. Expected to crest around magnitude –7, more than ten times brighter than Venus, it should have been visible to the naked eye during daylight.

Kohoutek wound up barely bright enough to spot with the naked eye at night. But the word didn't get out in time. Even in the December issue, astronomer Brian Marsden of the Smithsonian Astrophysical Observatory said the comet "is living up to our prediction concerning its brightness and tail." By the time Kohoutek became an official dud in January, the damage had been done. It took years before most of the media would trust astronomers' comet predictions.

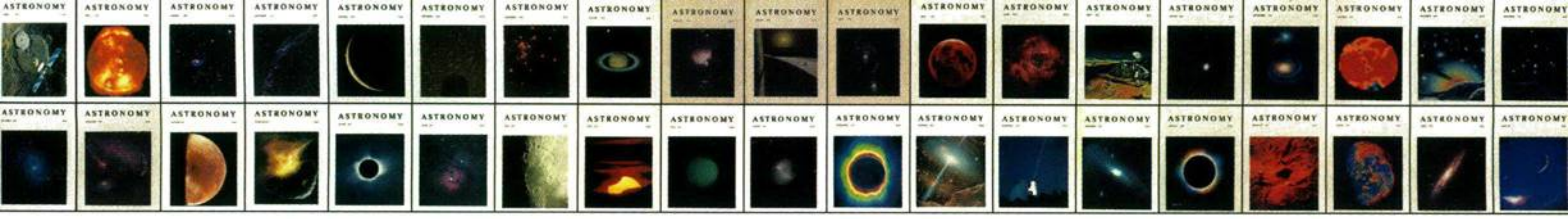
Mars also figured prominently in 1973, but with far better results. The Red Planet reached a favorable opposition late that year, prompting detailed articles on how to observe it. Many of the people who will be viewing Mars during the current great apparition cut their observing teeth with the magazine's help 30 years ago. Meanwhile, planetary scientists related their ongoing attempts to understand Mars. In the October issue, Carl Sagan made the first of many appearances in *Astronomy*, writing about the planet's enigmatic moons, Phobos and Deimos.

December 3, 1973, marked the first time a spacecraft ventured to a planet beyond Mars. The February 1974 issue featured a 15-page report on Pioneer 10's flyby of Jupiter. The treatment turned into a tradition at *Astronomy*, and each new

COMET KOHOUTEK FIZZLED in early 1974, glowing barely bright enough to see with the naked eye. EWELL SCHIRMER

SPECTACULAR COMET WEST followed two years after Kohoutek and provided a much better show for those in-the-know. RONALD ROYER

Rich Talcott *is senior editor of* Astronomy *and a charter subscriber to the magazine.*



encounter sparked a lengthy recap of the best images and science results. In the days before the Internet and 24-hour news channels — and with a media that had grown blasé about space exploration since the early Apollo Moon landings — science magazines proved indispensable to anyone interested in NASA's latest triumphs.

The June 1974 issue featured two important stories. The first summarized recent results from NASA's planetary missions, most notably the March 1974 flyby of Mercury by Mariner 10. But a smaller story, the lead in that month's AstroNews section, heralded a more important discovery.

For more than a decade, quasars and BL Lacertae objects had remained enigmas. These objects have huge redshifts, indicating they lie in the distant universe, but at the time, they appeared as just points of light. Most astronomers thought they were the bright cores of distant galaxies, although their ability to generate so much energy remained a mystery. A few believed they might be nearby objects ejected from galaxies. Caltech astronomers J. B. Oke and James Gunn managed to take a spectrum of the faint fuzz surrounding one of these objects, proving it to be a remote galaxy. The discovery essentially wrapped up the distance debate. It took researchers many years, however, before they realized that the energy source of a quasar must be material falling into a supermassive black hole.

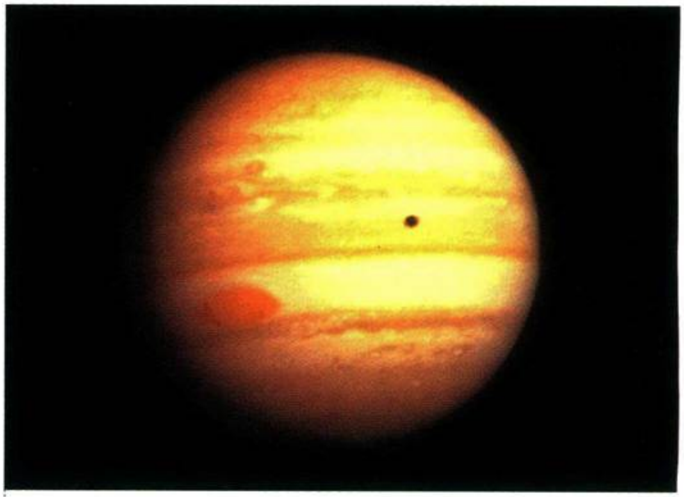
By the end of *Astronomy*'s first year, the magazine's formula was pretty well set. Each issue contained two or three science features as well as AstroNews and several other departments geared to hobbyists. Through the years, thousands of men and women built their own telescopes under the guidance of "Equipment Atlas," millions of images resulted from the helpful hints in "Photography in Astronomy," and countless observers learned about the sky's wonders and how best to view them. And all that information was packaged together with beautiful color pictures from professional observatories and talented amateur photographers and space art that took readers to places cameras could not.

Two Vikings and a comet

The mid-'70s brought a return to Mars, by both NASA and the magazine. In July 1975, *Astronomy* introduced another of its ongoing traditions: the spacecraft preview. The article detailed what the twin Viking missions would do once they reached Mars in 1976, explaining both what scientists expected and hoped to find. The Viking results proved spectacular, filling many pages in late 1976 and 1977. Although the biological experiments on the landers proved inconclusive, the first precise surface measurements and high-resolution color images from orbit remained the best available for more than 20 years.

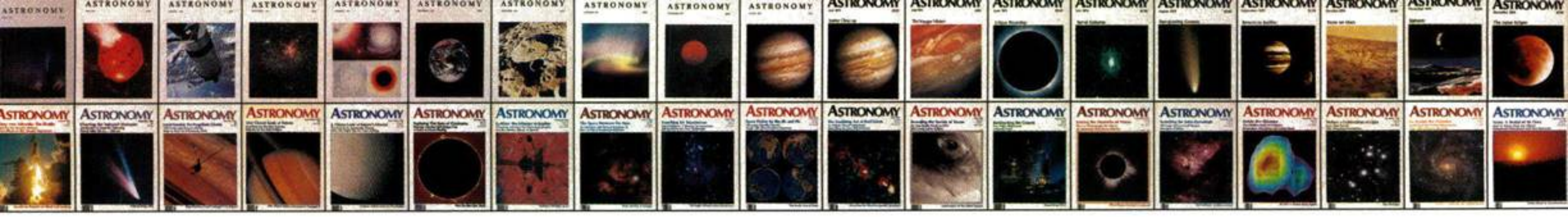
The observing highlight of 1976 had to be Comet West. But if you weren't an *Astronomy* reader, you might have missed it. Untold numbers never even heard about Comet West because most newspapers and television stations ignored it in the wake of Kohoutek's disappointing display. West easily turned into

THE LARGEST VOLCANO in the solar system, Mars's Olympus Mons, appeared in all its glory to the Viking orbiters. NASA/JPL



PIONEER 10 REVEALED JUPITER up-close for the first time. NASA/JPL

VOYAGER SAW JUPITER in far greater detail than Pioneer ever did, particularly in the intricate cloud patterns near the Great Red Spot. NASA/JPL



the comet of the decade, a spectacular morning object that reached magnitude –2 or –3. Great photos graced our pages for several months — and returned frequently in succeeding years' comet articles.

The year of the United States' bicentennial also brought *Astronomy*'s first special issue: July's history of astronomy in America. (The cover appropriately spotlighted the North America Nebula.) Ten separate articles traced the evolution of astronomy from prehistoric times to the lunar landings and beyond.

The November 1976 issue presented the first preview of the Space Telescope, then scheduled for launch in the early 1980s. The article provided a rationale for why astronomers wanted to observe from above Earth's distorting atmosphere and what they hoped to learn. Surprisingly, perhaps, most of the details ended up on target — except the launch date, of course, which fell back to 1990.

> **From both a visual and scientific standpoint,** nothing could compare with the Voyager flybys of Jupiter and Saturn.

The top news story of 1977 was the discovery of rings around the planet Uranus. On March 10, Uranus passed in front of the 9th-magnitude star SAO 158687. Astronomers watching saw the star's light dip five separate times before it reached Uranus's limb, evidence of a set of encircling rings. The December issue featured a full-length article on the subject. It asked the questions: "Why do Saturn and Uranus have rings? Perhaps more important, why don't Jupiter, Neptune, or any of the inner planets have any?" Although hindsight may be 20/20, foresight is decidedly myopic — Jupiter and Neptune do have rings, we now know.

For planetary buffs, 1979 may rank as *Astronomy*'s pinnacle. First, the April issue detailed the latest findings from the 1978 Pioneer Venus mission. Five probes explored the planet's thick atmosphere, which produces a greenhouse effect that raises the planet's surface temperature up to 850° Fahrenheit.

But from a visual standpoint, nothing could compare with the Voyager flybys of Jupiter. The May issue included 22 pages on March's Voyager 1 passage, and September's issue presented 18 pages on the Voyager 2 encounter in July. No one really knew what to expect. Pioneers 10 and 11 had shown a planet with a banded atmosphere that lacked intricate detail. Many thought a deep layer of haze hid the planet's most interesting aspects. Yet Voyager revealed an atmosphere roiling with activity. Fierce jet streams drove material in Jupiter's atmosphere, and complex features like the Great Red Spot changed as the spacecraft watched.

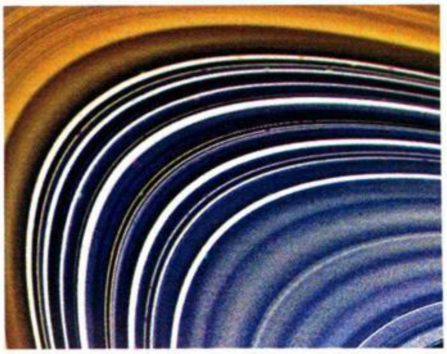
Just as exciting, the Voyagers showed that the four Galilean moons are worlds of their own. This nearly doubled the number of big rocky objects astronomers could study in detail. Io features massive erupting volcanoes, making it the most geologically active body in the solar system; Europa's lack of impact craters puzzled scientists, who later concluded that an ocean exists beneath an icy crust; part of Ganymede's surface appears ancient, while the rest shows intriguing grooved terrain suggestive of early geologic activity; and Callisto is chock-a-block with craters and apparently is the oldest surface in the solar system.

As if that weren't enough, Pioneer 11 flew past Saturn in September. The November issue showcased the first close-up photos of the Ringed Planet (or at least the first known ringed planet). As with the Pioneers at Jupiter, this mission tantalized researchers; the major discoveries would have to wait for the Voyagers to arrive in the 1980s.

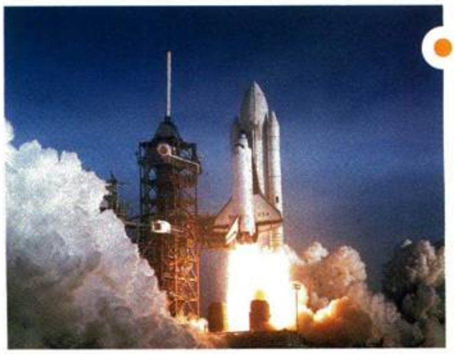
The long voyage continues

If there's been a lull in professional astronomy during the past 30 years, it happened in the 1980s. Great discoveries continued, but the means for making those discoveries didn't change very much.

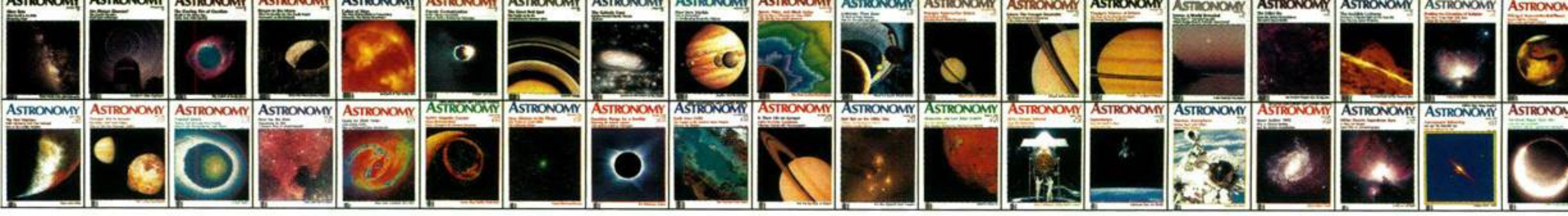
TURNING DISTANT MOONS INTO WORLDS, Voyager revolutionized our understanding of Ganymede and its grooved terrain. NASA/JPL



RINGS BY THE THOUSANDS greeted the Voyager spacecraft when they passed by Saturn in the early 1980s. NASA/JPL



SPACE SHUTTLE COLUMBIA lifted off from Cape Canaveral, Florida, on April 12, 1981, inaugurating a new method for reaching space. NASA



If you compiled a list of the biggest telescopes in the world in 1989, it would read pretty much the same as it did in 1980. The great planetary missions of the '80s were completed, for the most part, by spacecraft that began their journeys in the 1970s.

The same can't be said for developments in the amateur community. By the early 1980s, big telescopes became much more common. The "Dobsonian revolution" (started by John Dobson in the 1970s) allowed amateurs to build their own 10-, 12-, 16-inch or bigger scopes. *Astronomy* and its sister publication, *Telescope Making*, helped popularize the design. The June 1980 issue of *Astronomy* contained the first of a three-part series on how to build a Dobsonian.

An introduction to another technological revolution appeared in the November 1980 issue. An article described how professional astronomers were taking advantage of CCD imaging techniques. Although it took a decade for the technology to become inexpensive enough for amateurs to jump on the bandwagon, astronomy enthusiasts got a glimpse of the future.

In 1981, breathtaking images of Saturn returned by the twin Voyager spacecraft filled the pages of *Astronomy*. Both January and February issues contained 17-page articles on Voyager 1's flyby in November 1980, and the November issue devoted 25 pages to the story of Voyager 2's August encounter — the longest story in the magazine's history. These stories and others told of a planet unlike the one scientists expected. Before the flybys, astronomers could count the number of known rings on one hand. Afterward, the number of individual ringlets jumped to more than 100,000. As with Jupiter's moons, those circling Saturn were transformed from points of light into worlds. The thick atmosphere of Titan, the varied terrain of Enceladus, the differing hemispheres of Iapetus, and a huge crater on Mimas were all seen either for the first time or with better resolution than before.

The United States also found a new way into space in 1981. The first space shuttle launch took place in April, and *Astronomy* covered it in detail in the August issue. The title of the article — "Space Shuttle: Triumph over Tribulation" — still seems appropriate, but there have been a few times when the comparison could have been reversed.

The 1980s also saw the appearances of what were to become annual features of the magazine. The October 1983 issue contained the first "Buyer's Guide to Astronomical Telescopes," while the January 1989 issue featured the first "Sky Guide" detailing observing highlights for the coming year. Both stories have since migrated to the magazine's *Explore the Universe* annual.

The observing story of the decade, however, was the long-awaited return of Comet Halley. The build-up to Halley exceeded that for Kohoutek, and even though Halley never appeared bright, it pleased the public. Most seemed happy just to see the comet, not caring that it looked less than spectacular. *Astronomy* devoted hundreds of pages to Halley in 1985 and 1986, looking at its history and observing prospects, ongoing science discoveries, and international space missions. Our October 1985 special issue proved to be the best-seller of our first 20 years.

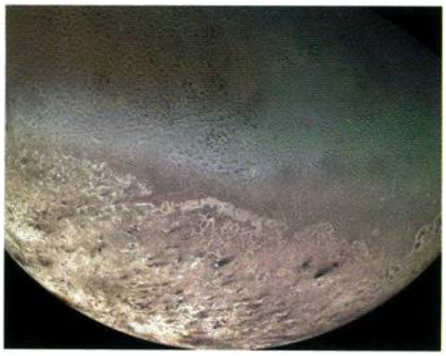
While Voyager 1 made a beeline out of the solar system, Voyager 2 headed on to Uranus and Neptune. Its encounters in January 1986 and August 1989, respectively, were the final planet flybys of the century. As it did at Jupiter and Saturn, Voyager 2 returned stunning photos of the atmosphere, rings, and moons of both Uranus and Neptune.

The explosion of Supernova 1987A in the Large Magellanic Cloud in February 1987 was a watershed. For the first time since the invention of the telescope, astronomers were able to scrutinize a nearby supernova and, in most cases, confirm their theoretical models of how massive stars explode. Most importantly, a pair of detectors built to study subatomic particles caught elusive neutrinos produced as the star's core collapsed.

Three comets and a Hubble

As the 1990s dawned, two new planetary explorers were on their way. The big news in space, however, was the impending launch of the Hubble Space Telescope (HST). Several stories leading up to the April 1990 launch touted Hubble's remarkable capabilities and predicted revolutionary breakthroughs. But reality fell far short. By the October issue, the truth was out: Hubble suffered from spherical aberration. The mirror had been polished superbly, but to the wrong figure — leaving Hubble unable to

COMET HALLEY SOARED into view in early 1986, providing people with both a satisfying sight and a link to past generations. NASA/JPL



NEPTUNE'S MOON TRITON greeted Voyager 2 with an odd mixture of ancient terrain and recent geologic activity. NASA/JPL

WHEN SUPERNOVA 1987A (the bright object at right center) exploded, it could be seen with the naked eye from Earth. MARCELO BASS, CTIO/NOAO/AURA/NSF

sharply focus light. Although it managed to limp along for three years, HST was a mere shell of what everyone had hoped.

Fortunately, planetary missions fared better. Magellan entered orbit around Venus in mid-1990, and first results were announced in the magazine's December issue. Magellan used radar to map the planet's surface through the opaque cloud layers, revealing impact craters and large volcanoes. Most significantly, the maps enabled planetary scientists to deduce that a great volcanic flood ravaged the venusian surface as recently as 600 million years ago.

The Galileo spacecraft took a more circuitous route to its destination, Jupiter. It flew past Venus once and Earth twice to gain the velocity needed to reach Jupiter. It also flew past two asteroids — Gaspra and Ida — on its way through the asteroid belt, giving scientists their first close-up look at these minor planets. It even found the first asteroidal moon, dubbed Dactyl, orbiting Ida. Dozens of articles related Galileo's discoveries to our readers, both on the road to Jupiter and after its arrival in December 1995. Its greatest triumph: showing that Europa almost certainly possesses a large ocean of liquid water beneath its icy crust.

A small meteorite designated ALH84001 made its first appearance in Astronomy in August 1995, before sparking a debate that still rages today.

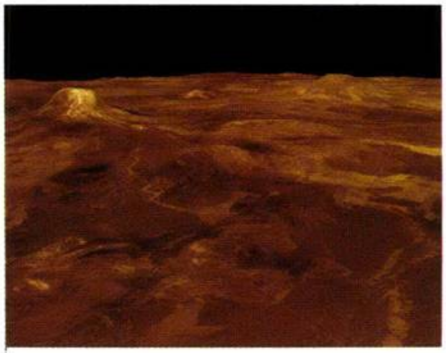
The 1990s saw more than its share of observing treats as well. The path of the longest total solar eclipse since the magazine's inception spanned from Hawaii to Mexico and into Central and South America on July 11, 1991. *Astronomy* started covering the eclipse in detail a year ahead of time, continuing a tradition that started with the February 1979 eclipse. The magazine provides a preview of each major total eclipse, explaining the best places to view them. We also sponsored a photo contest for the July 1991 eclipse, and several thousand entries vied for recognition in our November recap.

The June 1992 issue detailed one of the most surprising stories of the past 30 years. Astronomers had long been searching for planets around stars beyond our solar system, and in 1992, they found the first. But instead of circling a normal Sun-like star — as everyone expected — planets were found orbiting a pulsar. These superdense objects are the remains of stars that exploded as supernovae and are about the most inhospitable environment you could imagine for planet formation. To add to the irony, the discovery came on the heels of another announcement about pulsar planets that turned out to be false.

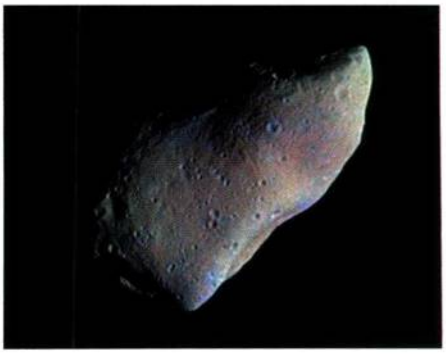
Two months later, *Astronomy* reported the findings of the Cosmic Background Explorer (COBE) satellite. Not only did COBE confirm the temperature profile of the background radiation left over from the Big Bang, it also detected tiny temperature fluctuations that trace density enhancements that grew into the galaxy clusters we see today. That same August issue brought our first report on results from the new 10-meter Keck Telescope on Mauna Kea, Hawaii, the first of 13 giant telescopes — all bigger than the largest scopes in existence before 1991 — to come on-line in the past dozen years.

The first computerized go-to telescope introduced another technological revolution for hobbyists in the early 1990s; *Astronomy* reviewed the Meade LX200 in July 1993. Go-to scopes automatically find a given object in the sky with little or no effort on the observer's part. Although some seasoned observers disdain these scopes, many novices swear by their ability to quickly locate faint objects.

Two events dominated the astronomical news in 1994. The first Hubble servicing mission in December 1993 set the stage for Hubble's remarkable resurrection. Astronauts replaced one of Hubble's instruments with a set of high-tech spectacles, allowing the telescope to see with the clarity it was designed to produce. The March 1994 issue related the story of the daring rescue



MAGELLAN'S RADAR PEELED BACK the clouds of Venus and revealed a planet with extensive lava flows from the fairly recent past. NASA/JPL



GALILEO VIEWED GASPRA from a few thousand miles away in 1991, providing the first close-up look at an asteroid. NASA/JPL

THE TOTALLY ECLIPSED SUN on July 11, 1991, shines down on Mauna Kea, home to many of the largest telescopes in the world. OLUF NIELSEN

mission. By the April 1994 edition, the first glorious pictures came out. And in September, we announced that Hubble finally had confirmed the existence of black holes. By taking detailed measurements near the center of the galaxy M87, Hubble showed that a supermassive black hole with some 2 billion times the mass of the Sun must lurk in the galaxy's heart.

The other big story was Comet Shoemaker-Levy 9. Although the comet wasn't spectacular visually, its effects were dramatic. In 1992, the comet passed close to Jupiter, whose immense gravity split it into 20-odd pieces. In July 1994, all the comet's pieces smashed into Jupiter, producing dark splotches in the jovian cloudtops that were easily seen from Earth. *Astronomy* previewed the collision in June and reported on observations from around the world in October, November, and December.

A small rock designated ALH84001 made its first appearance in the pages of *Astronomy* in August 1995. Scientists confirmed this meteorite, found in Antarctica in 1984, belongs to a rare class of meteorites from Mars. A year later, in November 1996, we detailed the stunning claim by NASA scientists that microfossils existed in the rock. They made a good case — as did their detractors — and the debate over whether these structures represent the remains of primitive life still rages vociferously.

The first planet around a Sun-like star was discovered in late 1995. The star 51 Pegasi harbors a planet (about half the mass of Jupiter) in a tight orbit (less than Mercury's distance from the Sun). In the April 1996 issue, we highlighted this planet along with two more recent discoveries. To date, more than a hundred extrasolar planets have been found. All are much more massive than Earth, but as techniques continue to improve, we may one day find solar systems that look more like ours.

Comet observers loved the 1990s. Comet Hyakutake sped into the inner solar system in early 1996. It arrived so quickly that *Astronomy* barely had time to report on it before the comet peaked. When at its best in March, it sported a tail that stretched nearly 100° across the sky, making it among the longest comet tails ever recorded.

Comet Hale-Bopp took a more leisurely path. Discovered in 1995, it didn't peak until early 1997. It proved brighter than Hyakutake but sprouted a shorter tail; backyard observers still debate which comet was better. Readers simply reveled in the spectacular photos splashed across our pages during '96 and '97.

July 1997 brought another planetary mission to the fore. Mars Pathfinder and its included rover, Sojourner, returned the first close-up images from the martian surface since Viking some 20 years earlier. The stunning images, detailed meteorology, and accurate mineralogy provided evidence that water once flowed on Mars. Combined with data from the orbiting Global Surveyor and Odyssey spacecraft, there's little question that water played a big role in the history of Mars.

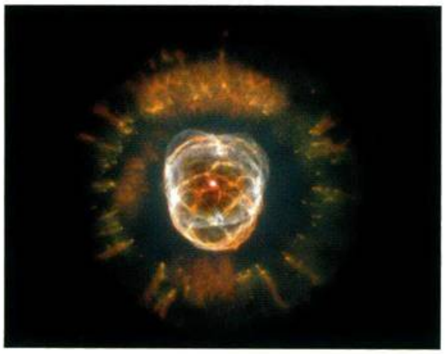
Among the photographs returned by Mars Pathfinder were amazing 3-D images. They formed the backbone of *Astronomy*'s first 3-D issue, in March 1998. Photos of Earth, the Moon, other solar system objects, and even deep-sky objects rounded out the 3-D extravaganza.

The Hubble Space Telescope played a key role in perhaps the most significant story of the new century. Observations show that distant supernovae are slightly dimmer than expected. The simplest conclusion: The expansion rate of the universe is accelerating, apparently driven by a still-mysterious "dark energy" that makes up some 65 percent of the universe's content. Dark matter — most likely in the form of low-luminosity objects like brown dwarfs or black holes, or exotic subatomic particles, or both — makes up nearly 25 percent. The normal matter that forms us, our planet, our solar system, and most everything else we know, constitutes less than 10 percent.

As *Astronomy* enters its fourth decade, who knows what lies in store. We know Mars will appear grand in the sky this summer. We expect great results from ongoing space missions: Cassini at Saturn, the deluge of Mars missions, and, of course, Hubble. We also anticipate continuing discoveries from the array of new, large, ground-based telescopes. We hope for more great comets and clear, dark skies. Whatever the future brings, you can count on *Astronomy* to bring the universe home to you. ■

What are your favorite stories from *Astronomy*'s first 30 years? We'd like to hear from you at www.astronomy.com/toc

THE HUBBLE SPACE TELESCOPE receives regular servicing missions; these help keep it an unsurpassed science instrument. NASA



THE ESKIMO NEBULA was captured by Hubble's WFPC2, an instrument that compensates for the telescope's flawed optics. NASA/STScI

MARTIAN METEORITE ALH84001, seen here before it was split open, harbored structures that some scientists interpreted as microfossils. NASA

30 years: looking back

Astronomy has evolved into the leading magazine of its genre in the world. /// BY DAVE EICHER

1973

Founder, publisher, and editor Stephen A. Walther pursues his dream of creating a popular astronomy magazine, organizing and incorporating AstroMedia Corp. in September 1972 and preparing the first issue by the spring of 1973. **AUGUST:** First issue of *Astronomy* published; speckle interferogram of the star Betelgeuse graces the cover, which resembles *Scientific American* with its white border; consists of 48 pages. **OCTOBER:** Third issue features Mars article by Carl Sagan and preview of upcoming Comet Kohoutek appearance. Circulation: approximately 10,000

1974

MARCH: Mariner 10 passes Mercury. **SEPTEMBER:** Stephen Walther named editorial director; Terence Dickinson editor. **DECEMBER:** Pioneer 11 passes Jupiter. Circulation: 23,593

1981

APRIL: First space shuttle flight is a success. **AUGUST:** Voyager 2 encounters Saturn. Circulation: 138,415

1982

SEPTEMBER: AstroMedia acquires *Deep Sky Monthly*, a magazine begun by high-school student Dave Eicher, and begins publishing it as a quarterly, retitling it *Deep Sky*. Eicher is hired as *Deep Sky's* editor. Circulation: 188,308

1983

JUNE: Pioneer 10 leaves the solar system. Circulation: 145,581

1984

Circulation: 131,839

1985

Kalmbach Publishing Co. purchases AstroMedia Corp. and begins publishing *Astronomy*, *Odyssey*, *Telescope Making*, and *Deep Sky*. Circulation: 151,771

1986

JANUARY: The space shuttle Challenger explodes, killing its crew of seven. Voyager 2 encounters Uranus. **MARCH:** Comet Halley puts on its best show since 1910. Circulation: 174,452

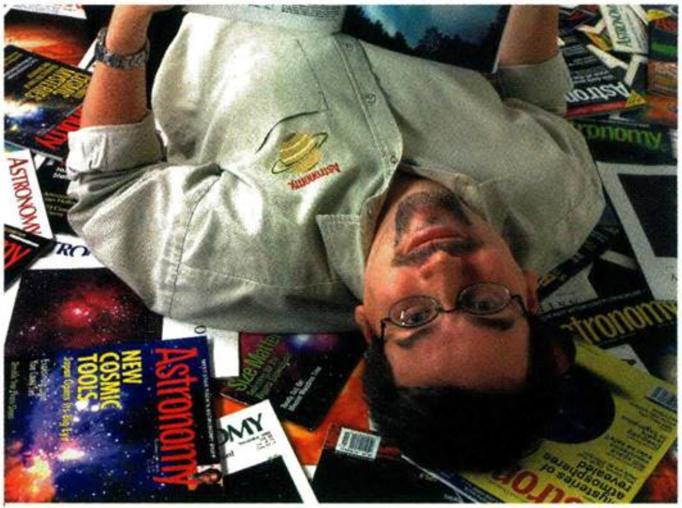
198

Little did Steve Walther know that his brainchild would turn into the greatest magazine about astronomy in the world. At 29, the ambitious graduate of the University of Wisconsin-Stevens Point launched a periodical about his first love, the stars. The first issue, August 1973, held 48 pages including five feature articles and information about what to see in the night sky that month.

Walther had grown up in the Milwaukee area and taken jobs in public relations after college, always at least dabbling in his beloved pursuit of astronomy. He worked part time as a planetarium lecturer at the University of Wisconsin-Milwaukee and developed a keen interest in photographing constellations. His gift to the world would live on, but sadly, he would not.

With the magazine catching on rapidly, Walther threw a party for contributing authors, photographers, and sponsors in the summer of 1976. Beside a pool, surrounded by drinks and hors d'oeuvres, talking his best game with his closest friends, Steve Walther collapsed, insensible. He died the following year, the victim of a brain tumor.

I never met Steve Walther. As he toiled through his illness, I was hundreds of miles away — a teenager — working on my own little publication, *Deep Sky Monthly*, a journal about observing



DAVE EICHER, editor of *Astronomy*, has been active as an astronomer and writer since 1976. He founded *Deep Sky* magazine and edited it for 15 years. He has written or edited seven books on astronomy. He was recognized by the International Astronomical Union with the minor planet 3617 Eicher. Contact him at editor@astronomy.com. *ASTRONOMY:* WILLIAM ZUBACK

1975

JANUARY: The magazine swells to 80 pages; features articles by George Abell and William K. Hartmann. **JULY:** Apollo 18 ends an era of exploration. Circulation: 40,007

1976

JULY: Viking 1 lands on Mars. **AUGUST:** Steve Walther diagnosed with a brain tumor after collapsing at a party. **SEPTEMBER:** Viking 2 lands on Mars. Circulation: 51,107

1977

MARCH: Rings of Uranus discovered. **SEPTEMBER:** On September 14, Steve Walther dies at age 33. **DECEMBER:** Richard Berry becomes *Astronomy*'s editor. Circulation: 58,063

1978

AstroMedia begins publishing *Telescope Making*, a quarterly, with Richard Berry as editor. **DECEMBER:** Pioneers arrive at Venus. Circulation: 85,049

1979

MARCH: Voyager 1 encounters Jupiter; AstroMedia begins publishing *Odyssey*, a children's magazine of astronomy, with Nancy Mack as editor. **JULY:** Voyager 2 encounters Jupiter. **SEPTEMBER:** Pioneer 11 passes Saturn. Circulation: 97,773

1980

NOVEMBER: Voyager 1 encounters Saturn; *Astronomy* becomes the top-selling astronomy periodical in the world. Circulation: 122,412

FEBRUARY: Supernova 1987A erupts in the Large Magellanic Cloud. Circulation: 163,187

1988

Circulation: 164,967

1989

AUGUST: Voyager 2 encounters Neptune. Circulation: 160,664

1990

APRIL: Hubble Space Telescope launched into orbit. **SEPTEMBER:** Magellan spacecraft starts mapping Venus. Circulation: 157,949

galaxies and clusters with small telescopes. But I was fortunate to meet and make friends with many who knew him, many who had worked with him. Reeling from the loss of leadership, the company Walther had started — AstroMedia Corp. — brought in Richard Berry to become editor and Bob Maas to take the publisher's helm.

Together, Berry and Maas forged *Astronomy* into a solid, respectable, and exhilarating package showcasing the best astronomy had to offer throughout the late 1970s and early 1980s. Berry and his coworkers presided over one of the most exciting periods in the history of modern astronomy, covering the Voyager missions to the planets in spectacular detail. They guided the magazine through the period in which it became the largest circulation astronomy publication in the world — larger than the long-established, conservative *Sky & Telescope*; larger than the Japanese leader, *Tenmon Gaido*. Berry also helped engineer the creation of an offshoot magazine, *Odyssey*, aimed at young minds, and the specialized quarterly publication *Telescope Making*, a significant force in the heyday of the Dobsonian revolution.

When I arrived in 1982, hired by Richard Berry, I brought my magazine, *Deep Sky*, now re-launched as a quarterly, and joined the *Astronomy* staff as the most junior of members. AstroMedia had gone through several rented offices, and by now it had its own distinctive stone building near Milwaukee's lakefront — one that had been a bar, complete with mud wrestling matches, prior to a publishing house. The 40 people who worked for AstroMedia consisted of a dozen or so editorial types and many other personnel — the marketing people, circulation gurus, advertising managers, and so forth. The whole place had the feel of an extended family, a kind of loose astronomy club that got together every morning to make a magazine.

Aside from the Big Hair and the Reagan Revolution, the early '80s were a quiet time in which the AstroMedia crowd excelled at producing and evolving its magazines' content. At mid-decade, however, lightning struck when Kalmbach Publishing Co., a Milwaukee publisher famous for *Model Railroader* and *Trains* magazines, purchased AstroMedia and began publishing the four astronomy titles. We left our bar/building and were absorbed into the Kalmbach family, in another part of town, adjusting to corporate culture as we ramped up for the appearance of Halley's Comet and lived through the sadness of the Challenger disaster. Senior editor Rich Talcott, a formidable veteran among the maga-

1991

JANUARY: Cosmic Background Explorer satellite data help confirm Big Bang theory; Kalmbach sells *Odyssey* to Cobblestone Publishing Co. **APRIL:** Compton Gamma-Ray Observatory launched. Circulation: 162,023

1992

FEBRUARY: Kalmbach discontinues *Deep Sky* and *Telescope Making*. **APRIL:** The Keck Telescope becomes the world's largest. **MAY:** Robert Burnham becomes *Astronomy*'s editor. **SEPTEMBER:** Mars Observer launches; communication lost 11 months later. Circulation: 168,460

1993

1998

JANUARY: *Explore the Universe 1998* sells 83,581 copies. Circulation: 190,663

1999

JANUARY: *Explore the Universe 1999* sells 73,978 copies. **FEBRUARY:** Stardust comet mission launched. **JULY:** Chandra X-ray Observatory launched. **SEPTEMBER:** Mars Climate Orbiter spacecraft lost. **DECEMBER:** Mars Polar Lander spacecraft lost. Circulation: 182,346

2000

JANUARY: *Explore the Universe 2000* sells 75,885 copies. **DECEMBER:** Cassini spacecraft passes Jupiter. Circulation: 168,859

2001

JANUARY: *Explore the Universe 2001* sells 70,944 copies. **FEBRUARY:** The NEAR-Shoemaker spacecraft lands on the asteroid 433 Eros. **APRIL:** Mars Odyssey mission launches; will support 2004 Mars rovers. **AUGUST:** Genesis solar wind sample return mission launches; will carry back particles from the solar wind to a helicopter for rescue. **NOVEMBER:** Leonid meteor "storm" thrills observers. Circulation: 161,114

2002

JANUARY: *Explore the Universe 2002* sells 68,635 copies. **JUNE:** Dave Eicher becomes *Astronomy*'s editor. **JULY:** CONTOUR spacecraft launched; comet mission subsequently lost. **NOVEMBER:** Leonid meteor shower more active than usual, again wows observers. Circulation: 157,772

zine's history, joined the staff at this time and has been an engine of creativity ever since.

With the end of the decade came a move to Kalmbach's new glass-and-steel headquarters in suburbia. Soon thereafter came transition: Richard Berry left the company, and Kalmbach discontinued publishing *Deep Sky* and *Telescope Making* and sold *Odyssey* to a company in New Hampshire.

Robert Burnham became the magazine's editor and we carried on as Comet Shoemaker-Levy 9 slammed into Jupiter, reminding us of Earth's vulnerability. We featured numerous breathtaking images captured with the newly repaired Hubble Space Telescope, a phenom rescued from failure. The late 1990s gave us two spectacular comets, Hyakutake and Hale-Bopp, and we debated the potential existence of life on Mars as allegedly captured in a Red Planet meteorite. *Astronomy* lost one of its best friends when Carl Sagan died well before his time.

Also in the late 1990s, Kalmbach created a web site, Astronomy.com, to support the magazine. Its staff, Andrea Gianopoulos, Vanessa Thomas, and Jeremy McGovern, has made great strides in creating supplemental material for issues of the magazine and making the magazine more visible the world over.

After holding just about every other job one can have at *Astronomy*, I became its editor in 2002. This year we re-launched the magazine with a sharper science focus and considerably expanded and improved coverage of the hobby of astronomy, with a special focus on telescopes and observing. We had a melancholy start of the year with the Columbia tragedy; however, we are very much enjoying this summer's wonderful opposition of Mars.

The story of *Astronomy* magazine is really a story of the people behind it. Dedicated by an obsession with the subject of astronomy, they are driven to assemble the best, most absorbing material relating to the world of astronomy with every page they create. Names such as Walther, Berry, Maas, and Burnham long ago established the magazine's stable foundation (and we are fortunate to have Robert Burnham working with us yet today as a contributing editor); the future will expand on this terrific first 30 years. Names such as Talcott, Bakich, McKee, Lantier, Baird, Quandt, and Ford will carry on this tradition of excellence. I am honored to work with each of our editors every day. Keep a close eye on their work in the pages of *Astronomy*; they are the stars of tomorrow. I think Steve Walther would be proud of them. I know that I am. ■

DECEMBER: An ambitious spacewalk repairs the flawed Hubble Space Telescope. Circulation: 204,624

1994

MAY: Annular eclipse of the Sun washes over the United States. **JULY:** Comet Shoemaker-Levy 9 slams into Jupiter. Circulation: 171,301

1995

JANUARY: *Astronomy* launches its first annual issue, *Observer's Guide 1995*, which sells 69,975 copies. **DECEMBER:** Galileo spacecraft arrives at Jupiter. Circulation: 159,957

1996

JANUARY: Extrasolar planets discovered in Ursa Major and Virgo; *Observer's Guide 1996* sells 64,288 copies. **MARCH:** Comet Hyakutake thrills observers with its long tail. **AUGUST:** Martian "microfossils" claimed found in meteorite. **NOVEMBER:** Bonnie Gordon becomes *Astronomy*'s editor. **DECEMBER:** Carl Sagan, friend of *Astronomy*, dies; Mars Global Surveyor spacecraft launched. Circulation: 171,226

1997

JANUARY: *Astronomy*'s annual *Explore the Universe 1997* sells 78,808 copies; Clyde Tombaugh, discoverer of Pluto, dies. **MARCH:** Comet Hale-Bopp dominates the sky. **JULY:** *Astronomy* redesigned; adopts a full-bleed cover; Mars Pathfinder lands on the Red Planet and the Sojourner rover explores it. **OCTOBER:** Cassini launches toward Saturn. Circulation: 181,959

2003

JANUARY: *Explore the Universe 2003* sells 58,655 copies. **FEBRUARY:** The space shuttle Columbia disintegrates on reentry, killing its crew of seven. **MARCH:** *Astronomy* is redesigned; adopts a mainstream science approach and beefs up hobby coverage of observing and telescopes. **MAY:** *Beginner's Guide to Astronomy*, an *Astronomy* special issue, is published. **AUGUST:** Mars puts on its best show ever, becoming closer and brighter than any other time in history. Circulation: 152,001

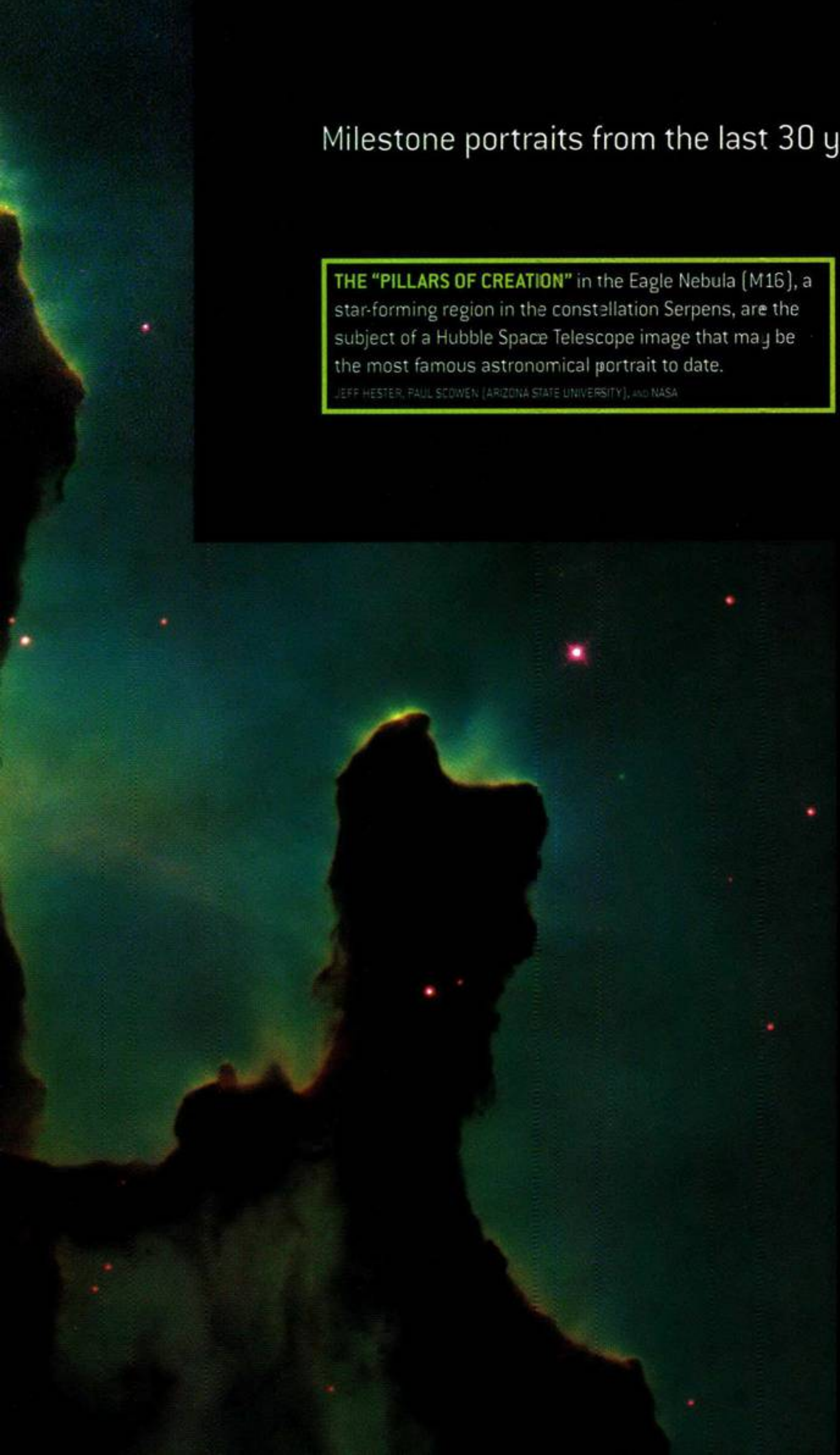
2004

Astronomy will carry on a tradition of excellence as the leader in its field, not only within the pages of the magazine, but in related products, with trips and tours, and special coverage of important sky events.

3

0 great astronomical images

Milestone portraits from the last 30 years of astronomy. /// BY TOM FORD



THE "PILLARS OF CREATION" in the Eagle Nebula (M16), a star-forming region in the constellation Serpens, are the subject of a Hubble Space Telescope image that may be the most famous astronomical portrait to date.

JEFF HESTER, PAUL SCOWEN (ARIZONA STATE UNIVERSITY), AND NASA

THE LAST 30 YEARS HAVE FLOODED US with astronomical surprises. Sometimes these discoveries came from breathtaking photographs — who can forget the Hubble Space Telescope's portrait of the Eagle Nebula (left)? Other findings stimulate our imaginations but pack less visual punch (for example, the controversial "evidence" of fossilized martian life on meteorite ALH 84001, page 59). More often than not, the image is the glue that keeps these stories stuck in our minds.

Here, then, are 30 striking — and in some cases, perplexing — images that changed our view of the cosmos in the last three decades. We hope this retrospective will bring back the same sense of awe and curiosity you felt when the images were first unveiled.

With so many dazzling portraits to choose from — most of which were produced within the last dozen years thanks to far-ranging spacecraft and powerful telescopes — it was hard to narrow the list down to those presented here. And the pace of discovery keeps accelerating — what wonders await us in the next 30 years?

Tom Ford is art director of *Astronomy*.

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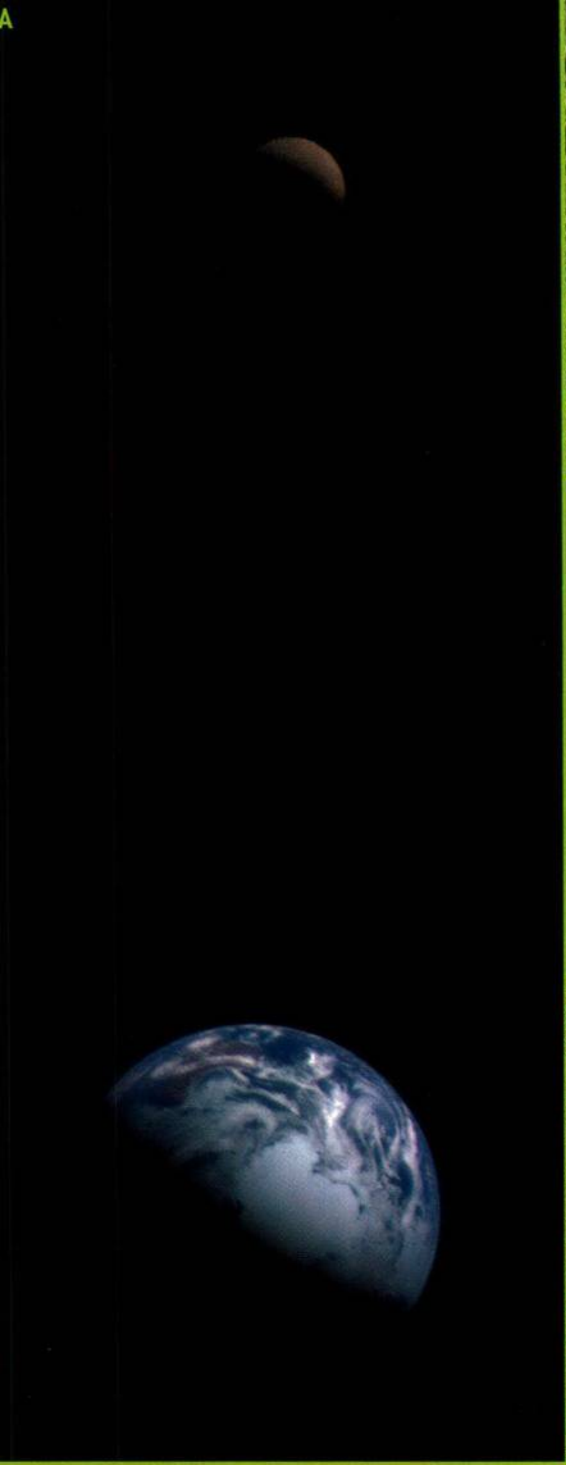

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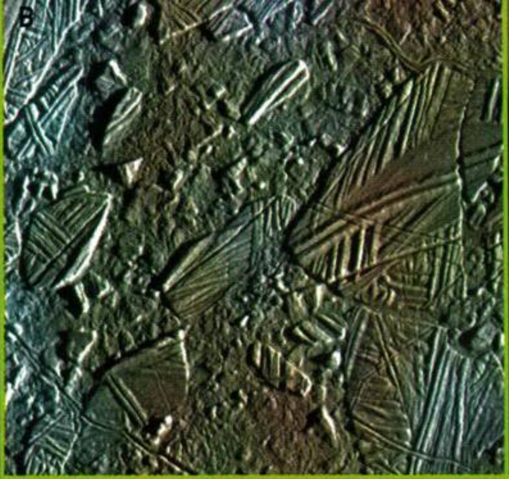

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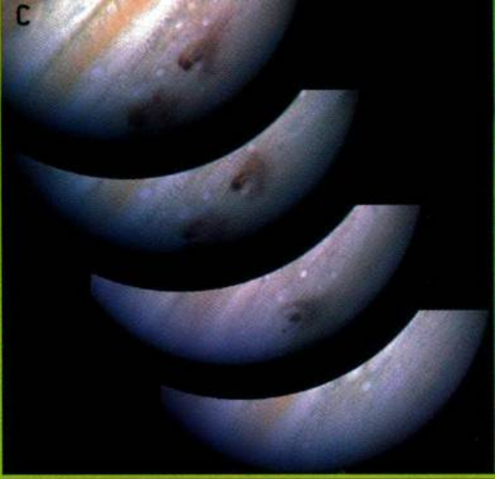

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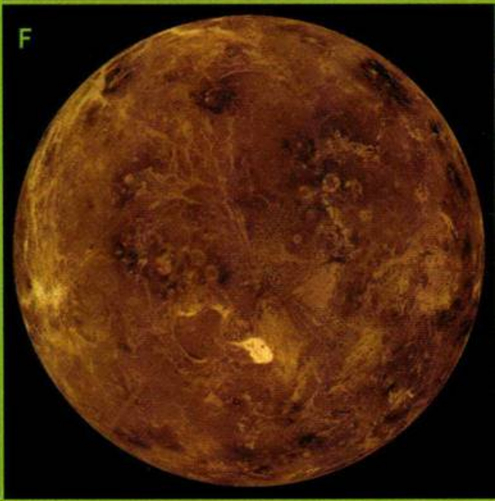

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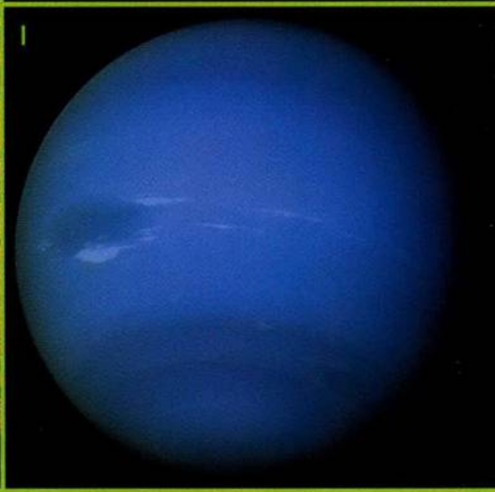

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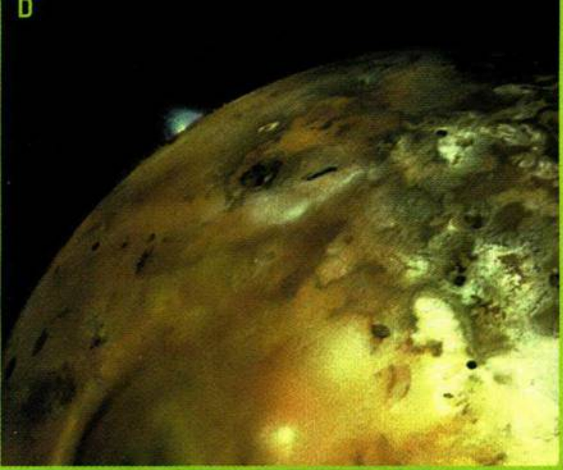

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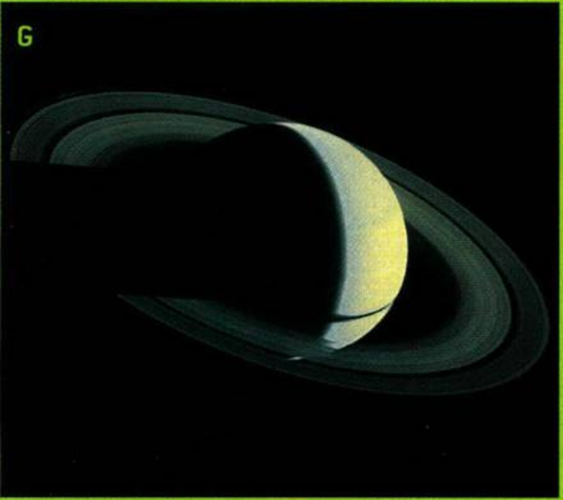

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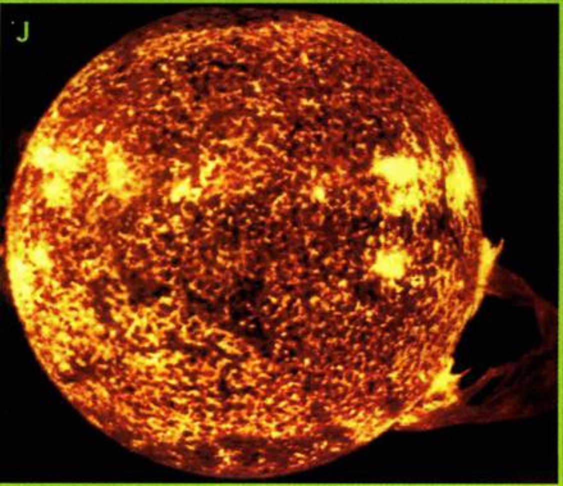
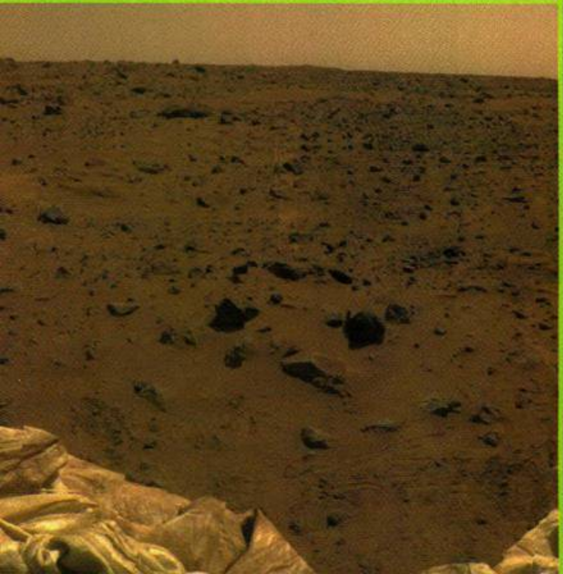




A] NASA'S NEAR EARTH ASTEROID RENDEZVOUS (NEAR) spacecraft, which was renamed NEAR Shoemaker for the late geologist Gene Shoemaker who studied asteroids, recorded this mosaic of Earth and Moon in January 1998, when it was approximately 250,000 miles away. To create this image, the Moon's apparent brightness was increased about fivefold. At the time, NEAR was using Earth's gravity to propel it toward asteroid 433 Eros (see page 57). NEAR SPACECRAFT TEAM, JHUAPL, AND NASA

B] THE LACK OF CRATERS on the surface of Jupiter's icy moon Europa took astronomers by surprise — only three craters wider than 3 miles have been discovered. Jupiter's gravitational tug rips scallop-shaped fissures into the ice that may be filled by a liquid water ocean 3 miles below the surface. These images were taken by the Galileo spacecraft, which arrived at Jupiter in December 1995 and will crash into the gas giant this month. PIRL/UNIVERSITY OF ARIZONA

C] COMET P/SHOEMAKER-LEVY 9's 21 fragments slammed into Jupiter in July 1994, marking the first observed collision between solar system objects. Occurring on Jupiter's far side, the impacts left large, dark wakes that rotated into view about an hour later. These overlapping images show Jupiter at various times after the crash of a fragment dubbed "G." In the first picture (lower right), Jupiter is unchanged after five minutes; after 1.5 hours, a dark plume rolls into sight; three days later, an additional impact site darkens its face; and after five days, a third impact site joins the group. R. EVANS, J. TRAUGER, H. HAMMEL, AND THE HST COMET SCIENCE TEAM; NASA

D] VOLCANIC ACTIVITY on Jupiter's moon Io was imaged during a March 1979 Voyager 1 flyby, offering the first proof of such activity beyond Earth. Gravitational pull from Jupiter and its moons Europa and Ganymede heats Io by bending it up to 330 feet out of shape. This tidal deformation helps make Io, which is about the size of our Moon, the solar system's most volcanically active object. JPL

E] MARINER 10, the only spacecraft to visit Mercury, snapped the planet's first close-ups during three flybys in 1974 and 1975. More than 2,300 images mapped half the rocky body's surface during the mission. These pictures helped discover a thin atmosphere made of atoms that the solar wind burned off of Mercury's pockmarked face. USGS

F] RADAR IMAGING TECHNIQUES were used by the Magellan spacecraft, launched in May 1989, to penetrate Venus's thick atmosphere. Earth-based radio telescopes and Russian probes had pierced the noxious carbon dioxide and sulfuric acid clouds earlier, but Magellan's view was unprecedented in its scope and clarity — it imaged 98 percent of the planet, resolving features about 330 feet long. The planet's tallest peak, Maxwell Montes, rises nearly 7 miles above the average elevation and shows up as the whitish blob just below center in this portrait of the northern hemisphere. JPL

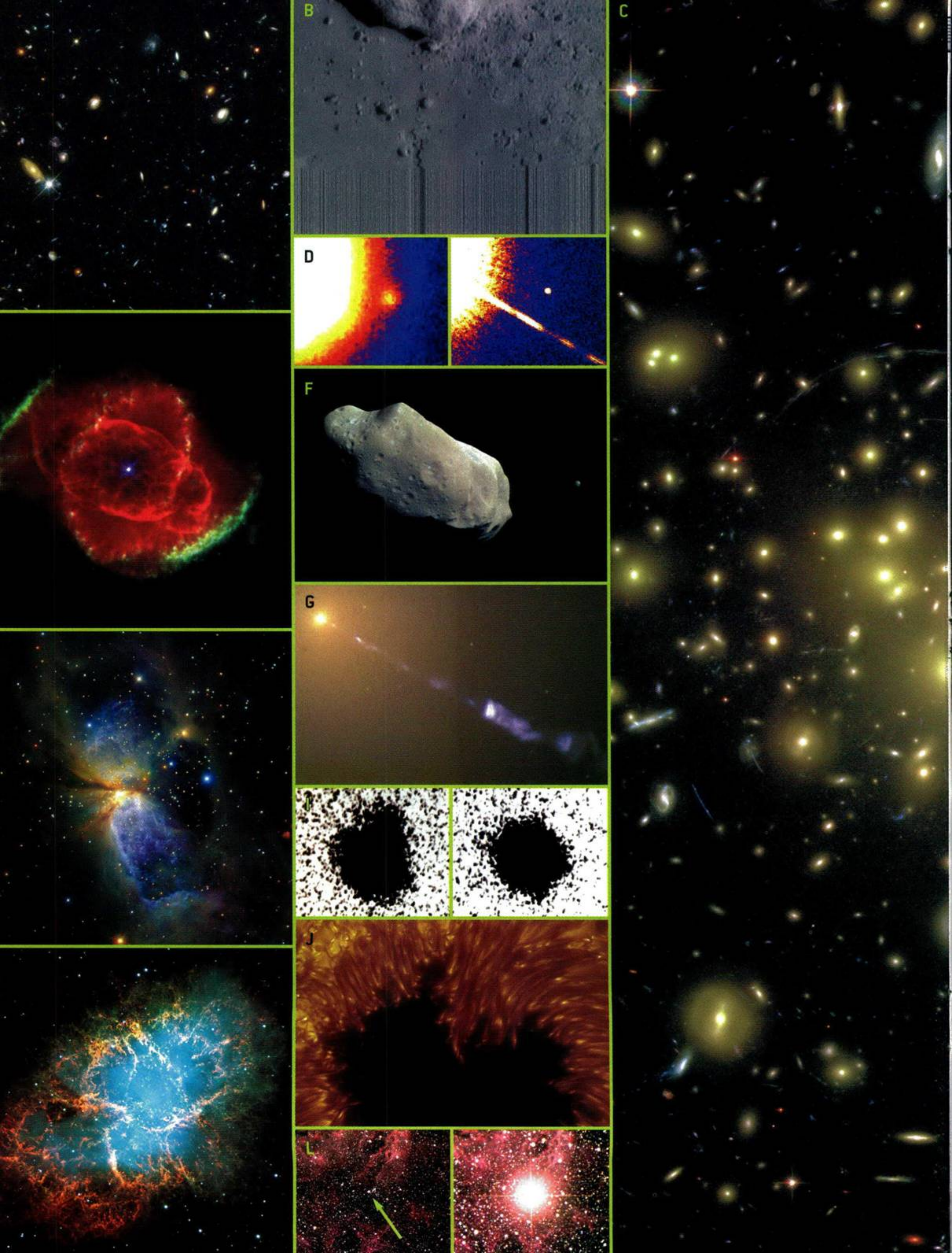
G] SATURN'S DRAMATIC CRESCENT PHASE is never visible from Earth because Earth lies within the Ringed Planet's orbit. The Voyager 1 spacecraft had to fly beyond Saturn to capture its dark side in this November 1980 image. The Cassini-Huygens spacecraft, due to arrive at Saturn in July 2004, will be the first to visit the planet since 1981. USGS

H] NOT UNTIL SATELLITES got a bird's-eye view of our home planet did geologists begin to recognize many impact craters on Earth. Eroded by wind and rain and constantly being repaved by plate tectonics, our world's surface shows little trace of the ancient bombardment seen on objects such as the Moon and Mars. About 150 terrestrial craters have been identified, including a string of them in Chad that may have been carved by an asteroid or comet that broke into pieces before impact. Radar imaging aboard the space shuttle Endeavour penetrated layers of sand in the Sahara Desert to capture the ringed topography seen in this 1994 image. JPL

I] THE GREAT DARK SPOT ON NEPTUNE, captured by the Voyager 2 spacecraft in 1989, was a storm so big it could have engulfed Earth. Neptune's winds are the fastest on any planet in the solar system; the spot, which hasn't been seen recently, tore through the atmosphere at about 750 miles per hour. Methane gas, which absorbs red light and comprises 2 percent of the planet, gives Neptune its sapphire hue. JPL

J] A HUGE SOLAR PROMINENCE was recorded by Skylab, the first U.S. space station, which launched into orbit on May 14, 1973. During its five years of operation, Skylab took more than 120,000 pictures of the Sun. SKYLAB, NASA

K] THE SOJOURNER ROVER examines Yogi, the large boulder (center) in the first contiguous 360° color panorama taken by the Imager for the Mars Pathfinder mission, launched in December 1996. The first mission completed in NASA's low-cost Discovery Program, Pathfinder was a success not only for science, but also for the agency, whose reputation suffered after it lost contact with the Mars Observer spacecraft in 1993. JPL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A] THE HUBBLE DEEP FIELD NORTH, located in the constellation Ursa Major, covers a spot of sky the size of a dime as seen from 75 feet away. Focused on the patch for 10 days, Hubble's Wide Field and Planetary Camera 2 combined 342 exposures and revealed more than 1,500 galaxies. Most of these are 4 billion times fainter than what we can see with our eyes alone, and some of them lie 10 billion light-years away, offering us a window to the early universe, when galaxies first started forming. R. WILLIAMS (STScI), NASA

B] LANDING ON EROS wasn't part of the original plan, but creative mission engineers managed the first-time feat, gently setting the NEAR-Shoemaker spacecraft down on the asteroid's surface. NEAR-Shoemaker snapped its last image of Eros from a height of 394 feet, showing a few of the thousands of boulders called "blocks" that geologists believe were ejected from craters on the asteroid. After touchdown on February 12, 2001, the probe's Gamma-Ray Spectrometer continued to transmit data for a week. JHU/APL

C] GRAVITATIONAL LENSING, captured in unprecedented detail in this image of the galaxy cluster Abell 1689, located in Virgo, demonstrates Einstein's prediction that gravity warps space and bends light. A trillion stars as well as unseen dark matter in the cluster, which lies 2.2 billion light-years away, refract light from more distant galaxies, pinching and smearing their images into rings. NASA, N. BENITEZ (JHU), T. BROADHURST (HEBREW UNIVERSITY), H. FORD (JHU), M. CLAMPIN (STScI), G. HARTIG (STScI), G. ILLINGWORTH (UCO/LICK OBSERVATORY), THE ACS SCIENCE TEAM, AND ESA

D] THE FIRST CONFIRMED BROWN DWARF was Gliese 229B in 1995. Astronomers had speculated about these middleweight objects, thought to be starved of the gas necessary to become full-fledged stars. Their dimness makes brown dwarfs hard to spot, and it took corroboration from three instruments to identify the first candidate (the image on the left is from the Palomar Observatory; the image on the right is from the Hubble Space Telescope). Gliese 229B, located in the constellation Lepus the Hare, is about 20 to 50 times Jupiter's mass and contains methane, just like the gas giants in our solar system. S. KULKARNI (CALTECH), D. GOLIMOWSKI (JHU), AND NASA

E] THE CAT'S EYE NEBULA (NGC 6543) puzzles astronomers with its elaborate configuration of glowing gas clouds, which may be the result of two stars at its center. Formed when a dying star puffed out its outer layers, this planetary nebula lies 3,000 light-years away in the constellation Draco. J. P. HARRINGTON, K. J. BORKOWSKI (UNIVERSITY OF MARYLAND), HST, AND NASA

F] EVEN ASTEROIDS HAVE MOONS, as the Jupiter-bound Galileo spacecraft proved in August 1993, when its CCD camera snapped the first image of the asteroid Ida and its tiny sidekick, Dactyl (right). JPL

G] A JET EMANATING FROM M87, an active elliptical galaxy 50 million light-years away in the constellation Virgo, offers strong support for the existence of supermassive black holes. At M87's center, a spinning black hole as massive as 2 billion Suns devours material from the stars and gas around it. Electrons and subatomic particles glow blue as they barrel at near-light speeds away from the object along the superhighway of its magnetic field lines. NASA AND THE HUBBLE HERITAGE TEAM (STScI/AURA)

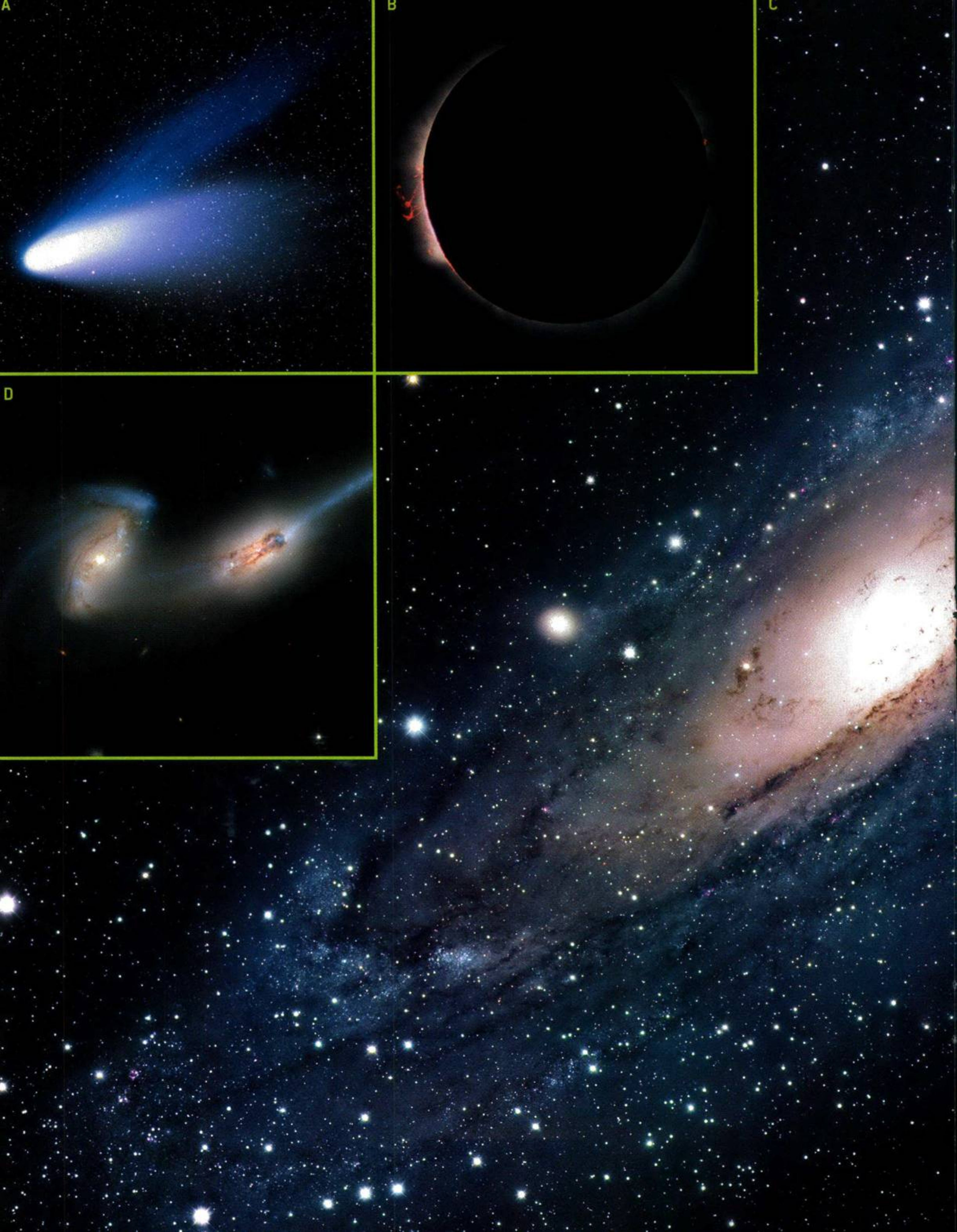
H] FREE-FLOATING OBJECTS the size of planets, some only a few times the mass of Jupiter, pepper the star-forming region S106 IRS4 in the constellation Cygnus. Because they don't orbit stars, the objects haven't been categorized yet, although the International Astronomical Union has tentatively dubbed them sub-brown dwarfs. The loners may have been en route to becoming stars when interactions in star-forming clouds jettisoned them into exile. NATIONAL ASTRONOMICAL OBSERVATORY OF JAPAN

I] PLUTO'S SATELLITE, CHARON, seen as a bulge on the left image (the moon is hidden from view in the right image), was discovered in 1978 by James Christy. At nearly half Pluto's size, this water-ice-covered moon and its host represent the solar system's nearest thing to a double planet. Pluto is one destination of NASA's recently approved New Horizons mission, expected to launch in 2006. U.S. NAVAL OBSERVATORY

J] THE SUN never looked so sharp as in this image taken at the Swedish 1-m Solar Telescope in the Canary Islands. Able to resolve details as small as 56 miles, the telescope, which became fully operational in May 2002, strutted its stuff with the best-ever view of filaments and a sunspot. Sunspots are dark because magnetic fields in and around them keep hotter gas below the solar surface. ROYAL SWEDISH ACADEMY OF SCIENCES

K] THE CRAB NEBULA in Taurus, imaged by the Very Large Telescope in 1999, is a dynamic supernova remnant also known as Messier 1. The star that created the Crab exploded in A.D. 1054 and was so bright it was visible during the day. EUROPEAN SOUTHERN OBSERVATORY

L] SUPERNOVA 1987A, located in one of the Milky Way's satellite galaxies, the Large Magellanic Cloud, was the first exploding star to be seen with the naked eye in nearly 400 years. Appearing on February 23, 1987, the type II supernova reached magnitude 2.9 three months later. The star was undistinguished before its eruption (left), but burned brightly several weeks afterward (right). ANGLO-AUSTRALIAN OBSERVATORY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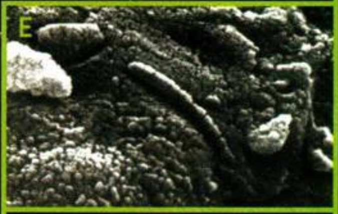
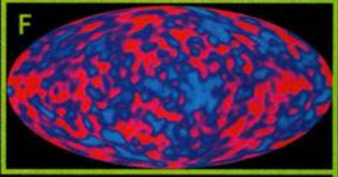




A] COMET HALE-BOPP, one of the most observed comets in history, was discovered in July 1995 by two amateur astronomers in the American Southwest: Alan Hale and Thomas Bopp. Last seen about 4,000 years ago, the comet came closest to the Sun (perihelion) on April 1, 1997. JOHN A. VOLK

B] THE SOLAR ECLIPSE ON JULY 11, 1991, not only treated lucky viewers in parts of the Americas to nearly seven minutes of totality, but also displayed prominences about 90,000 miles high. RAJIV GUPTA

C] THE ANDROMEDA GALAXY (M31), lying 2.6 million light-years away, was imaged by amateur astronomer Robert Gendler in 2002. The availability of CCD technology has helped amateurs' images rival those from professional observatories. This image is a mosaic of 40 separate frames taken during 10 imaging sessions. The cumulative exposure time for the mosaic was 40 hours. ROBERT GENDLER

D] THE MICE (NGC 4676A and B), a pair of colliding spiral galaxies in the constellation Coma Berenices, foretell what likely will happen to our own Milky Way a few billion years from now, when it smashes into our nearest neighbor, the Andromeda Galaxy. This image was one of the four that made front-page news when the Hubble Space Telescope's new Advanced Camera for Surveys flexed its muscles in April 2002. NASA, H. FORD (JHU), G. ILLINGWORTH (USCS/LO), M.CLAMPIN (STScI), G. HARTIG (STScI), THE ACS SCIENCE TEAM, AND ESA

E] EVIDENCE OF LIFE ON MARS may have been discovered in 1996, when possible fossilized microbes were seen in this 4.5-billion-year-old martian meteorite named ALH 84001, which was found in Antarctica. After years of heated debate, the exact nature of the microscopic, tube-like objects remains unknown. NASA

F] THE COSMIC MICROWAVE BACKGROUND EXPLORER (COBE), launched in 1989, gave us a very sensitive picture of what the universe looked like about 300,000 years after the Big Bang, when the first radiation was able to travel through space. The pink and blue regions show areas of the sky that are warmer and cooler, respectively, than adjoining regions by about one part in 100,000. Astronomers believe mysterious quantum fluctuations in the newborn universe created these so-called inhomogeneities, which were the seeds of structures such as galaxies and voids. This year, the Wilkinson Microwave Anisotropy Probe shed more light on these cosmic ripples. NASA

View from the mount

Birthplace of the discovery of the expanding universe, Mount Wilson Observatory offers astronomers some of the best seeing anywhere. /// BY SALLIE BALIUNAS

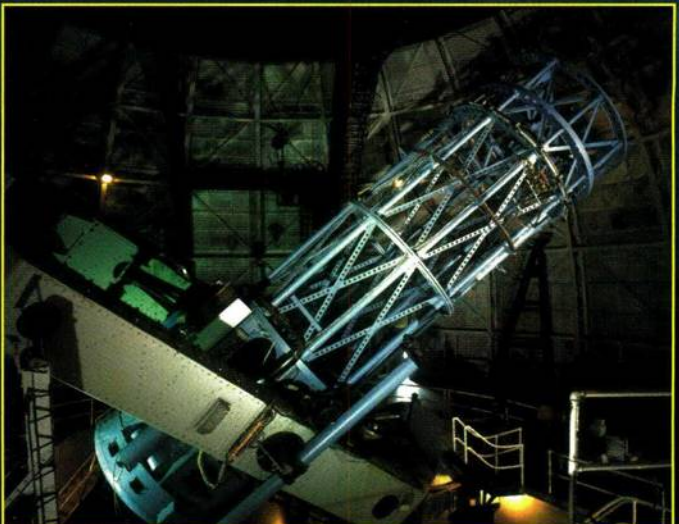
Twilight sinks into the jagged mountains, draining color first from the valleys, then from beneath the scrub oak and Coulter pines whose cones sway, fat with sap. Buildings fade from noontime's electric white to hoary gray to black silhouettes against the stars. Breezes bring air faintly scented of the sea as domes open to the night. On a mountaintop above Los Angeles, distant galaxies and stars have showered light onto the optics of powerful telescopes at the Mount Wilson Observatory for almost 100 years. The observatory is the legacy of one tireless individual, George Ellery Hale, who, while trained in solar physics,

STEVE PADILLA

aintop

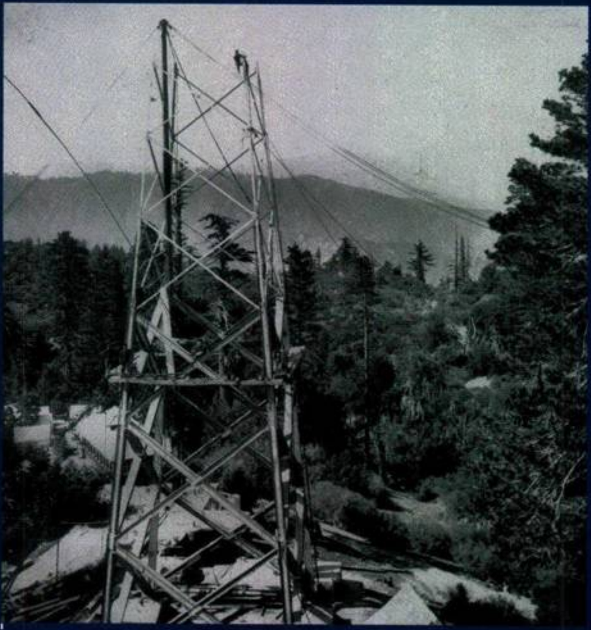
found his real calling making American astronomy foremost in the world. Even today, a year from its centennial, Mount Wilson is a testament to his boundless drive and ambition.

Hale (1868–1938) came from a wealthy background and hobnobbed easily with the industrial barons of the Gilded Age. Blessed with energy, organizational ability, and a flair for public relations, Hale swept through astronomy at the turn of the 20th century, when astronomers were changing emphasis from cataloging the positions of celestial objects to understanding how stars worked. Hale realized that as



THE 100-INCH HOOKER TELESCOPE, named for benefactor John D. Hooker, was the largest telescope of its day. A few years after it saw first light in 1917, Edwin Hubble used it to discover two profound facts about the universe — it stretches far beyond the realm of the Milky Way, and it is expanding. ERNIE WILLIAMS

"MAKE NO SMALL PLANS" was the motto of George Ellery Hale, the indefatigable astronomer who built the world's largest telescope four times in a row. Mount Wilson Observatory is home to two of them. COURTESY OF CARNEGIE OBSERVATORIES, CARNEGIE INSTITUTION OF WASHINGTON



THE SKY WAS THE LIMIT for Hale as he sought ever-better views of the Sun. In 1909, a year after he used Mount Wilson's 60-foot Solar Tower to discover that sunspots have magnetic fields, Hale started construction on the 150-foot Solar Tower, above. FERDINAND ELLERMAN, COURTESY OF CARNEGIE OBSERVATORIES, CARNEGIE INSTITUTION OF WASHINGTON

FEATS OF ENGINEERING were required not only in the design but also in the transportation of the observatory's great telescopes. In the summer of 1917, workers hauled the Hooker Telescope's 100-inch mirror up the mountain on a custom-built Mack truck. COURTESY OF D. ROSE AT REED'S CAMERA SHOP, PASADENA

astronomy became astrophysics, it would demand big telescopes with great light-collecting ability.

"Make no small plans," he decided.

In the 1890s, Hale persuaded a streetcar tycoon to build the largest telescope in the world, the 40-inch refractor at Yerkes Observatory in southeastern Wisconsin. Characteristically, even before Yerkes was finished, Hale already was planning his next big project. Through his father's generosity, Hale ordered a 60-inch-diameter glass disk for a reflector telescope larger than any in existence. Mirrors, Hale noted, can be supported at the back of the disk, unlike refractor lenses for which the 40-inch was, then and now, the practical limit. Mirror optics thus opened the road to vastly larger telescopes. With astronomy's future in mind, Hale designed the 60-inch telescope for astrophysical research, using photographic plates to capture images rather than an astronomer's eye and sketching hand.

As the 60-inch was being built, Hale convinced the Carnegie Institution of Washington to fund a new observatory in which to house it, support facilities, and several additional telescopes. Wisconsin's Yerkes Observatory suffered from cloudy skies, so he sought a clear-sky site. The solution he found was outstanding — and it's still paying dividends for astronomers. After carefully surveying several locations, Hale selected a wild 5,700-foot-high mountain named Wilson's Peak in the San Gabriel Mountains north of Los Angeles.

Star-test observations proved the astronomical seeing, or image steadiness, was exceptional owing to local geography and meteorology. Observations from the mountaintop are sharp because Wilson's Peak — soon renamed Mount Wilson — is tall enough that it juts above the so-called inversion layer capping the Los Angeles basin. In an "inversion" of the normal dropoff in temperature with height, smooth, tepid marine air rides atop chillier onshore breezes. This gives the lofty observatory spectacular seeing and helps telescopes work at high efficiency.

Daytime star

Hale's primary scientific interest was the Sun. Thus, in 1904, the Snow Solar Telescope became the first permanent instrument on Mount Wilson. The telescope uses a movable mirror to send sunlight into the horizontally mounted optics. But Hale found that daytime ground-heating degraded the resolution, so he built a 60-foot tower for the optics. At the top of the tower, the Sun-tracking mirror stands high above the trees; from there, sunlight is beamed down to instruments on the ground.

The 60-foot Solar Tower began operations in 1907. Its prime instrument, called a spectroheliograph, measures the Sun's spectrum and studies sunspots as they spin in and out of view due to the Sun's rotation. Hale found the spots' spectral lines indicate strong magnetic fields — up to 10,000 times that of Earth's. Ever the perfectionist, Hale sought even sharper resolution and built the 150-foot Solar Tower in 1912.

Astronomers at the observatory also studied the rise and fall in *numbers* of sunspots, which vary over about an 11-year period. In 1925, Hale and Seth Nicholson discovered a cycle twice as long when they looked at the spots' magnetism. For example, in one

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Sallie Baliunas *is an astrophysicist at the Harvard-Smithsonian Center for Astrophysics and has worked at Mount Wilson since 1976.*

11-year cycle, the leading spot in a pair displays positive polarity in the Northern Hemisphere (negative in the Southern). In the next 11-year cycle, the pattern of polarity in the leading spot reverses. Thus, it takes a total of 22 years for leading sunspots to return to the same polarity.

Expanding the universe

Yet solar studies were to be only part of Mount Wilson's repertoire. The 60-inch saw "first light" in 1908, and Walter Adams used it to study the spectra of stars, measuring velocities, chemical compositions, and variations.

In 1906, Hale ordered the mirror for a 100-inch telescope, nearly tripling the light-grasp of the 60-inch. After technical delays, first light reached the 100-inch in November 1917.

The two big telescopes — each, in succession, the world's largest — made fundamental discoveries. Harlow Shapley employed the 60-inch to extend the boundaries of the Milky Way, then regarded as the entire universe. He plumbed the distances to globular clusters, showing they lie tens of thousands of light-years away. And their locations in the sky revealed that the Sun and solar system do not take center stage in the Milky Way.

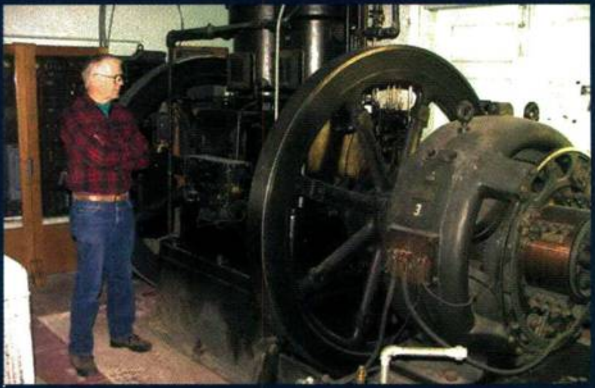
Yet the greatest work done at the observatory was discovering the nature of galaxies and the expanding universe. Through the 1920s and '30s, Edwin Hubble and his colleague Milton Humason showed that "spiral nebulae" were distant galaxies, each as vast as the Milky Way. Their work also showed that the more distant a galaxy appeared, the faster it seemed to recede. Thus the motions of galaxies trace the expansion of the universe from a beginning, now estimated at 13.7 billion years ago. This result fit predictions from Albert Einstein's theory of general relativity, and it established the field of observational cosmology. As astronomer Allan Sandage wrote in his book, *The Hubble Atlas of Galaxies,* "What are galaxies? No one knew before 1900. Very few people knew in 1920. All astronomers knew after 1924."

Postwar changes

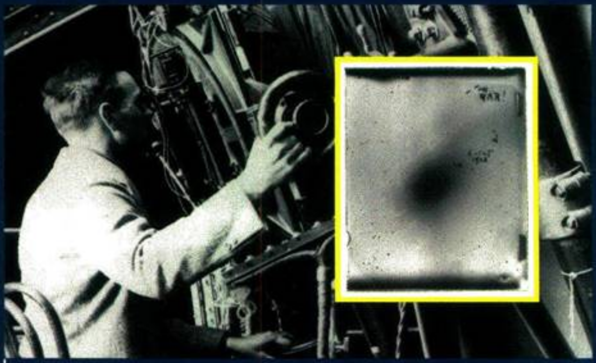
As Los Angeles grew after World War II, the skies brightened and Mount Wilson's fortunes declined. Hale saw it coming. In 1928 he began planning a 200-inch telescope on Palomar Mountain, in the dark-sky country between Los Angeles and San Diego. Delayed by the Depression and the war, first light for the 200-inch, named for Hale, came in 1948. Sadly, Hale died ten years before it was finished. With the arrival of the 200-inch, cosmology research shifted to Palomar and, later, to newer big telescopes at remote sites in Chile, Hawaii, and Australia. In the late 1960s, Mount Wilson Observatory also branched out with a new Southern Hemisphere station in Las Campanas, Chile.

Despite bright night skies, superb seeing has kept solar astrophysics thriving on Mount Wilson. Continually upgraded instruments at both towers provide state-of-the art digital data on the Sun, extending a decades-long record of solar change. The 60-foot Solar Tower, now managed by Ed Rhodes of the University of Southern California, continues to be a vital instrument. It's where Robert Leighton of the California Institute of Technology found five-minute oscillations on the solar surface, which launched the field of helioseismology, the study of the Sun's interior through its surface vibrations. (Helioseismology was developed by Roger Ulrich of UCLA, who leads the 150-foot Solar Tower program.)

MOUNT WILSON'S INCREDIBLE SEEING is due to its lofty height — at 5,700 feet above sea level, the observatory perches above the clouds in smooth, still air. STEVE PADILLA

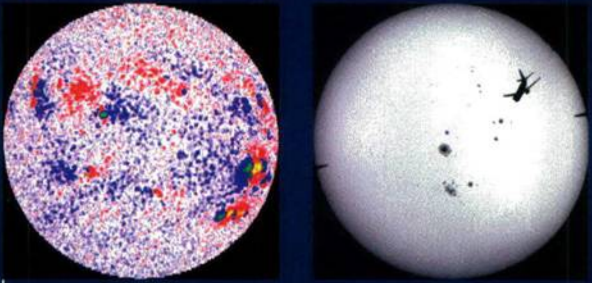


THIS GENERATOR PLAYED DOUBLE DUTY in the observatory's early days. The 50-horsepower, two-cylinder engine charged banks of batteries that powered the facility, and the water used to cool it down was drawn off for hot showers in the next room. GALE GANT



EDWIN HUBBLE, the brilliant lawyer-turned-astronomer who spoke with a phony English accent, joined the staff of the Mount Wilson Observatory in 1919. In the 1920s, he used the 100-inch Hooker Telescope [above] to prove that the smudgy "nebulae" on photographic plates were actually galaxies outside our own and that the universe is expanding. **CAREFUL SCRUTINY** of photographic plates led to one of Hubble's greatest insights. Instead of being an exploding star, or nova, as he originally thought, one star in the Andromeda "Nebula" brightened and dimmed in the characteristic fashion of a Cepheid variable. Calculating its distance from the equations of his day, he found the star could not possibly lie within our own galaxy, thereby settling a contentious debate — the universe was much, much larger than the Milky Way. After this epiphany, Hubble took his pen to the plate and scribbled "VAR!" [for variable]. COURTESY OF CARNEGIE OBSERVATORIES, CARNEGIE INSTITUTION OF WASHINGTON

STAR TRAILS STREAK past the 150-foot Solar Tower on a moonlit night. To keep the optics steady even in the wind, the tower is made up of two separate, but nested, structures — an inner beam that holds the 12-inch triplet apochromatic lens and an outer framework that supports the protective dome. STEVE PADILLA



THE SUN still takes center stage on Mount Wilson, as it has since the Snow Solar Telescope became the first operational instrument on the mountain in 1904. On May 5, 2003, the 150-foot Solar Tower took this magnetogram (left), which maps the Sun's magnetic fields. The observatory also boasts the world's largest collection of white-light photographs of our nearest star. Snapped every clear day of the year by a simple focal-plane camera built in 1905 and attached to the 60-foot Solar Tower, the photos chart the Sun's surface features over time. A jet (right) flew across the Sun's disk on July 25, 1991. LEFT: DATA FROM THE SYNOPTIC PROGRAM AT THE 150-FOOT SOLAR TOWER/UCLA, WITH FUNDING FROM NASA, ONR, AND NSF, UNDER AGREEMENT WITH THE MT. WILSON INSTITUTE. RIGHT: UCLA

At the 150-foot Solar Tower, Ulrich and his colleagues are continuing to study the Sun's magnetic field. The magnetograph, installed in 1953 by Horace Babcock, has been in constant use. There is now a 50-year record of solar surface magnetism, including complex flows and fluctuations. This lengthy and detailed observational record helps refine the solar dynamo model, which still cannot give good predictions on how the Sun's magnetic field changes over long periods.

New directions

In the 1980s, tightened finances forced the administrators of the observatory to shift its emphasis from the Mount Wilson site to Las Campanas, where dark skies and large telescopes still permit research on faint stars and galaxies. In response, astronomers from several institutions formed an independent Mount Wilson Institute to keep the observatory's telescopes operating.

The 100-inch telescope closed in 1984, but in 1994 the Mount Wilson Institute re-opened it with new computer-controlled pointing and tracking and adaptive optics. In this last technique, the surface of a flexible mirror dimples up to several hundred times per second to counteract blurring in the atmosphere. The adaptive optics system, built by Chris Shelton of the Mount Wilson Institute, yields images that are as sharp as the telescope's maximum theoretical performance — the views look as if the telescope were in space. Ancillary instruments, among them a high-resolution near-infrared camera built by Laird Thompson, hitchhike on the adaptive optics.

To remove a limitation in the adaptive optics that forces the system to look only at relatively bright stars, Thompson built a different instrument that shines a laser spot on the sky to detect the air's distortions near the object of interest, for example, the core of a galaxy. This system, which has just become operational, can take high-resolution extragalactic images.

Even sharper focus

Near the 100-inch, a new metal building hums as computers and lasers merge starlight from six 40-inch telescopes. The pictures they create are sharp enough to detect a nickel 10,000 miles away. When the six scopes join forces, they form the world's largest optical interferometer, or linked array. Together they have the resolution of a giant telescope with a diameter as large as their distance apart — a fifth of a mile. The interferometer is called the CHARA Array, for its parent institution — Georgia State University's Center for High Angular Resolution Astronomy. Another instrument on Mount Wilson, the University of California at Berkeley's Infrared Spatial Interferometer (ISI), views the sky at longer wavelengths.

These two interferometers take astrophysics into the 21st century. Interferometry is not new on the mountain; Albert Michelson measured star diameters in the 1920s with a 20-foot interferometer atop the 100-inch (see *Astronomy,* July 2003). But advances in technology now allow much larger baselines and higher resolution. CHARA can measure star diameters, luminosities, distances, and masses. It can search for evidence of extrasolar planets and image starspots on some stars. Similarly, ISI, led by Charles Townes, can penetrate nebulae obscured at visible wavelengths. This lets astronomers peer into the dusty environments that cocoon very young or very old stars.

/// VISITING MOUNT WILSON OBSERVATORY

Mount Wilson Institute
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Pasadena, California 91106
[t] 626.793.3100
[w] www.mtwilson.edu

The Institute's offices are in Pasadena, near the Caltech campus. To get to the observatory, take the Angeles Crest Highway (California Route 2) from Foothill Boulevard in La Cañada/Flintridge, just northwest of Pasadena. After 14 miles, turn right onto Red Box Road. (Be careful — many of the turns are blind and tight, and the road has no shoulders.) Five miles after that, you'll pass a group of TV and radio antennae on the way to the parking lot. The observatory gate is directly ahead.

Weather permitting, the observatory grounds are open weekends and some holidays from 10 A.M. to 4 P.M. between April 1 and November 30. Tours are held at 1 P.M. during daylight savings time. Parking is available inside the gate, as are picnic facilities (but bring your own drinking water in case it's not on tap). — *Robert Burnham*

Another project involves students. Gil Clark directs the Telescopes in Education project, which has worked with students in kindergarten through 12th grade in several hundred schools around the world for nearly a decade. The project uses 24-inch and 14-inch telescopes at the observatory, plus 14-inch telescopes in Chile and Australia. All are equipped with CCD cameras. Students control the telescopes remotely from their classrooms. They've searched for supernovae, assisted in planning for NASA missions, followed variable stars, and measured asteroid rotations and distances.

Hunting other suns

One project that would have greatly pleased Hale examines Sun-like and other cool stars for evidence of "starspots." Olin Wilson began the HK Project in 1966 to see if stars showed decade-long sunspot cycles like the Sun.

The project's name comes from the spectral lines of ionized calcium the project monitors: H and K. These lines are bright when magnetic fields on a star's surface cause spots and other Sun-like features. By measuring changes in the two lines over many years, Wilson found starspot cycles like the Sun's in some of his program stars.

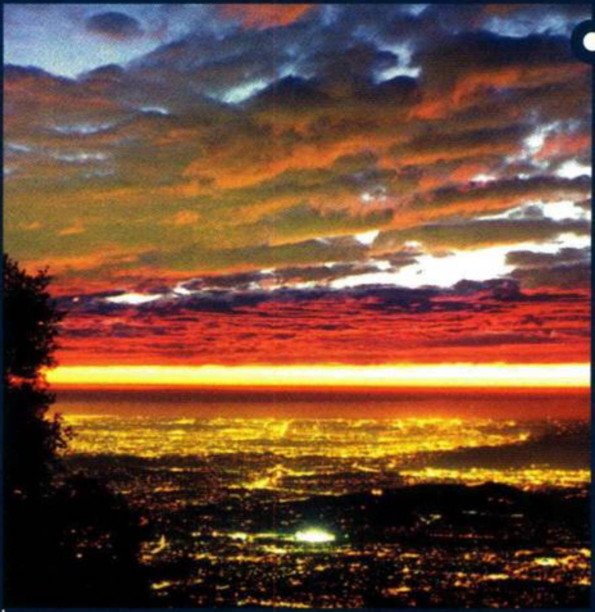
Wilson retired in 1978, but the program keeps expanding — to date, more than half a million measurements have been made of more than 3,000 cool stars. Project records extend through several starspot cycles, allowing scientists to study long-term changes.

Hale's legacy

As Mount Wilson enters its second century, studies of the Sun and other stars continue to benefit from the site's incredibly steady seeing. Advanced telescope technologies are bringing renewed activity to the mountaintop.

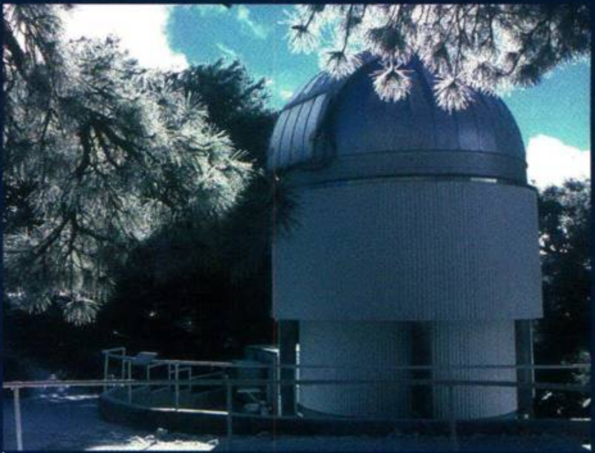
And George Ellery Hale's vision of an astrophysics laboratory is still expanding, just like the universe it discovered. ■

To learn more about Mount Wilson's fascinating history, including a timeline of its construction, visit www.astronomy.com/toc



LOS ANGELES FLOODS THE SKIES above Mount Wilson with as much light as the Full Moon — but blanketing clouds mitigate the effect when warm sea air blows over the city.

COLLEEN GINO, DUDLEY OBSERVATORY



SIX TELESCOPES, housed in domes like the one above, link up across Mount Wilson to form the world's most powerful optical interferometer. Called the CHARA Array, the scopes use vacuum tubes to combine light from each of their 1m-wide mirrors. CHARA can resolve a nickel at a distance of 10,000 miles. STEVE PADILLA

AN AURORA, rare at this latitude, glimmers above the 100-inch dome (background) and one of the three 65-inch telescopes that form the University of California at Berkeley's Infrared Spatial Interferometer (foreground). STEVE PADILLA

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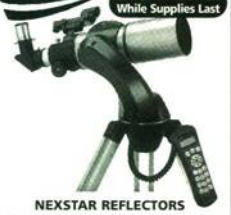

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BY MARTIN RATCLIFFE AND ALISTER LING

SEPTEMBER 03

Refresh your soul with starlight as often as you can, as the Northern Hemisphere enters what usually turns out to be its best observing season.

Mars remains big and bright

The Red Planet has just broken an historic record with its closest approach in more than 50,000 years. But there's no time to lose. Mars begins to shrink and fade this month following its opposition in late August. Like moving into a new neighborhood and gaining your bearings, you'll find it fairly easy to become familiar with martian surface features.

Mars is certainly worth making a fuss about. But in the sad event of a global dust storm obscuring all its surface features, take the opportunity to learn more about the distant gas giants. Uranus and Neptune are well placed in the early evening sky, floating in the distance behind Mars.

Earth's orbiting partner is worth watching this month. On the evening of September 2, a delightful crescent Moon passes in front of the bright double star Delta (δ) Scorpii, the middle star of the front claws of Scorpius. Just before 7 P.M. EDT, observers northeast of a line from Cape Cod to upper New York state are in for a treat. The Moon's knife edge slices this extremely close double star, making Delta Sco disappear in two steps rather than instantly. On the edge of the Moon's shadow, several mountain peaks will cut into the starlight causing spectacular multiple events for those in the viewing area.

THE STARS OF WINTER, including those in Taurus and Auriga, return to view on September mornings. In this view from 1987, a waning crescent Moon (lower left) joins the spectacle. JERRY SCHAD

You can bet that everyone out for an evening walk on the 8th and 9th will be impressed by the pairing of Mars and the Moon in the south. The Moon is just a day before full phase, but next month when it passes by, it will be noticeably less lit.

In the last week of September, sneak a peak at the eastern sky about 50 minutes before sunrise. The waning crescent Moon will be approaching Jupiter and lie beside it on the 24th. Mercury is a snap to see below and a little left of Jupiter during the next two weeks. You can just fit the pair in a wide-angle binocular view. Contrast the planets' brightnesses and colors with blue-white Regulus to Jupiter's upper right (as seen in the Northern Hemisphere).

Best of luck for transparent skies on the morning of September 25. An extremely thin crescent Moon, only 18 hours before its rebirth, lies just to the left of a line running from Jupiter through Mercury to the horizon.

The autumnal equinox falls on the 23rd at 6:47 A.M. EDT. If the 23rd seems late, you've fallen into a familiar trap. With the three previous equinoxes or solstices landing on the 20th or 21st of their months, it's easy to get in a habit of thinking of the 21st. But summer is the longest season, 93.65 days, compared with autumn which lasts only 89.94 days. This, combined with the number of months with 31 days in between, accounts for the apparent discrepancy.

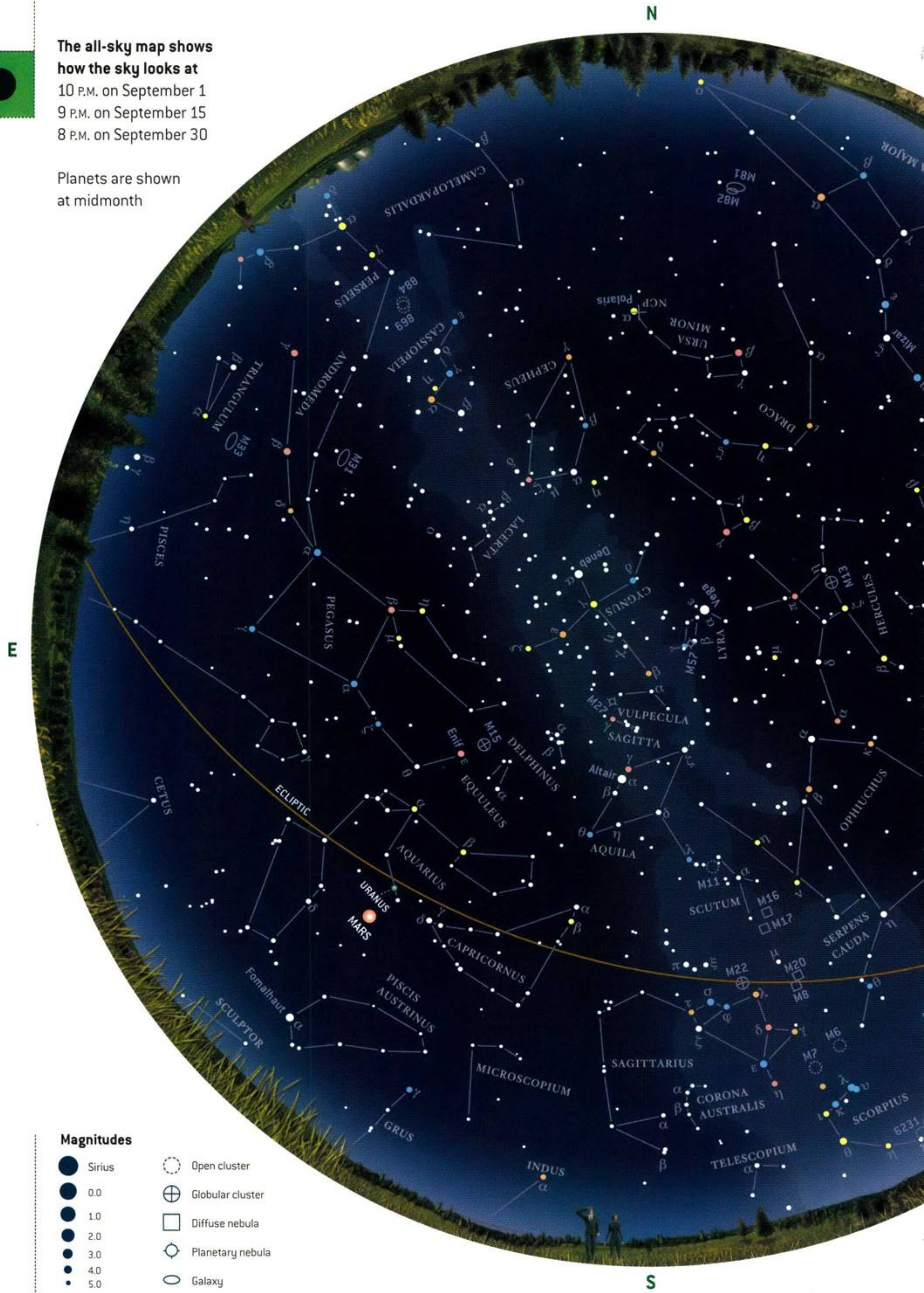
Don't forget to stay up to look at Saturn. It's moved a long way since spring and is now throwing off the symmetrical pattern of Gemini. Its ring system has started flattening, too.

Although there are no major meteor showers this month, there are several minor ones. You should see quite a few "shooting stars" while at a star party under a dark sky. Star parties often are scheduled in September because of the typically good weather.

Stargazing is so good for the soul you should observe as often as you can, even from a light-polluted backyard. Instead of hunting for galaxies, search for asteroids and double stars or follow changes in variable stars. The road to happiness is short when you're traveling at the speed of light.

The all-sky map shows how the sky looks at
10 P.M. on September 1
9 P.M. on September 15
8 P.M. on September 30

Planets are shown at midmonth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PEGASUS
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VULPECULA
SAGITTA
M15
Enif
DELPHINUS
EQUULEUS
Altair
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OPHIUCHUS
CETUS
ECLIPTIC
AQUARIUS
URANUS
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CAPRICORNUS
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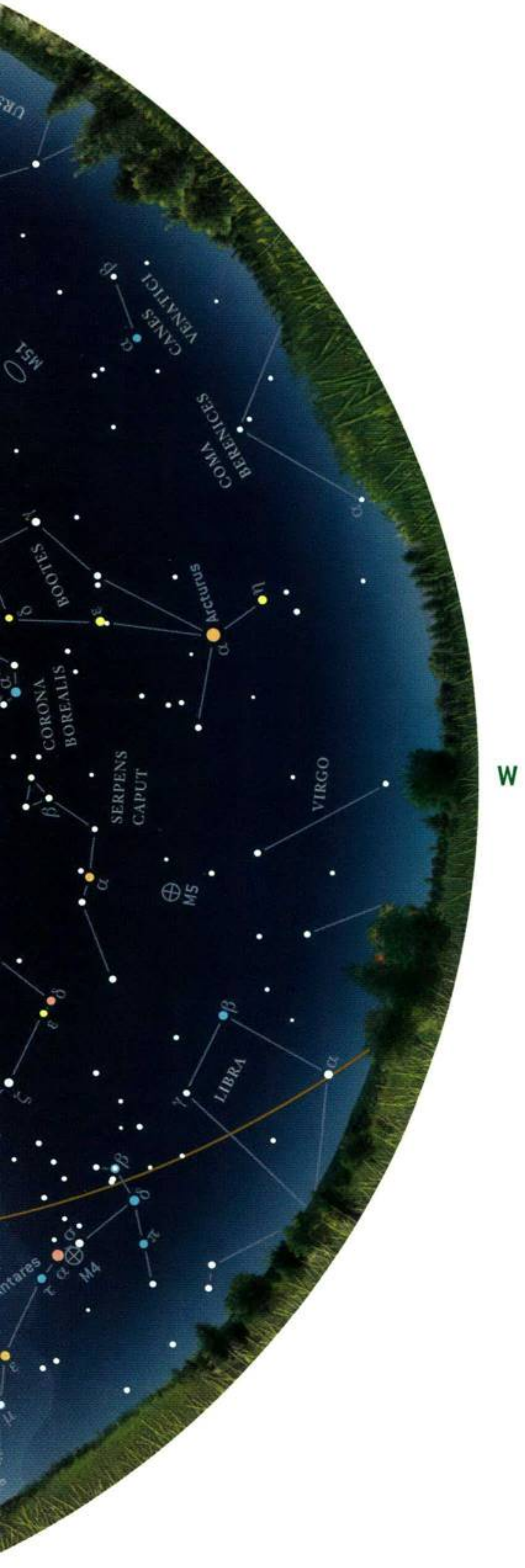
SCUTUM
M16
M17
SERPENS CAUDA
M22
M20
M8
Fomalhaut
PISCIS AUSTRINUS
SCULPTOR
MICROSCOPIUM
SAGITTARIUS
M6
M7
CORONA AUSTRALIS
SCORPIUS
GRUS
INDUS
TELESCOPIUM
6231

Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

This map portrays the sky as seen near 35° north latitude at times shown in the upper left corner of the page. Located just outside the map are the four directions: horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sk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BOOTES
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VIRGO
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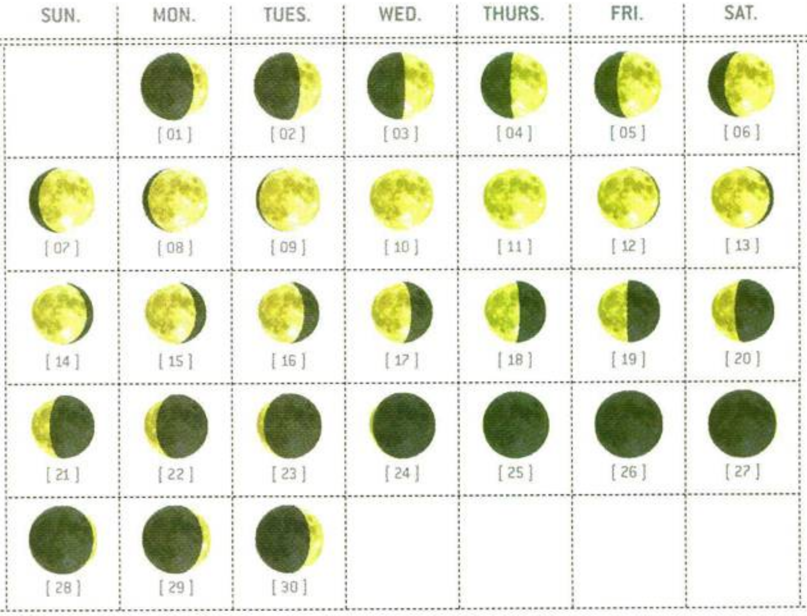
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03 First Quarter Moon is at 8:34 A.M. EDT

07 The Moon passes 5° south of Neptune, 3 P.M. EDT

09 The Moon passes 5° south of Uranus, 2 A.M. EDT

The Moon passes 1.2° north of Mars, 9 A.M. EDT

10 Full Moon is at 12:36 P.M. EDT

Mercury is in inferior conjunction, 10 P.M. EDT

16 The Moon is at apogee (251,477 miles from Earth), 5:22 A.M. EDT

18 Last Quarter Moon is at 3:03 P.M. EDT

19 The Moon passes 5° north of Saturn, 11 P.M. EDT

23 Autumnal equinox is at 6:47 A.M. EDT

The Moon passes 4° north of Jupiter, midnight EDT

24 The Moon passes 5° north of Mercury, 1 P.M. EDT

25 New Moon is at 11:09 P.M. EDT

26 Mercury is at greatest western elongation (18°), 8 P.M. EDT

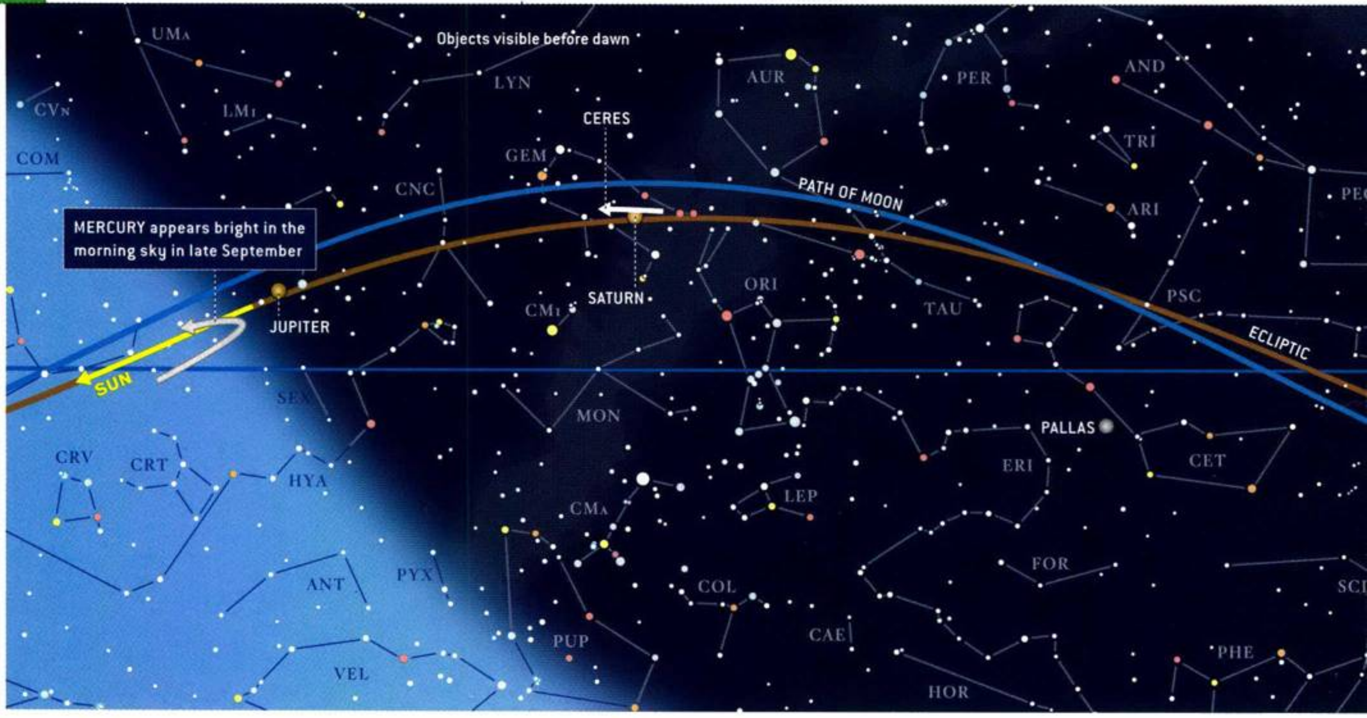
28 The Moon is at perigee (225,455 miles from Earth), 1:59 A.M. EDT

29 Mars is stationary, 10 A.M. EDT

north, south, east, and west. To find stars above your
y.

Planets this month

This map unfolds the entire night sky from sunset [at right] until sunrise [at left]. Arrows and sq


Objects visible before dawn
UMA
CVN
LMI
COM
LYN
CNC
GEM
CERES
AUR
PER
AND
TRI
ARI
PEG
PATH OF MOON
MERCURY appears bright in the morning sky in late September
JUPITER
SUN
SATURN
CMI
ORI
TAU
PSC
ECLIPTIC
SEX
MON
PALLAS
ERI
CET
CRV
CRT
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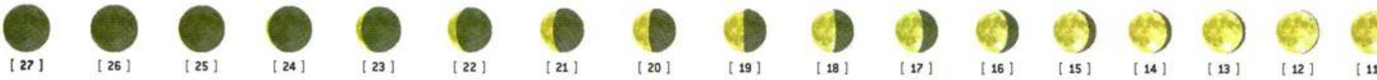
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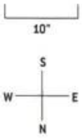
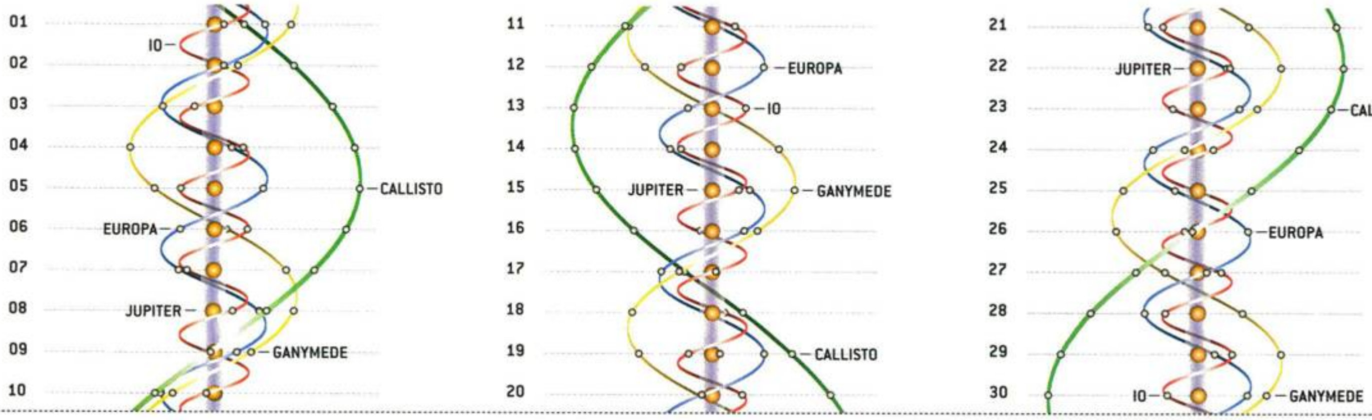
To locate the Moon in the sky, draw a line from the phase s



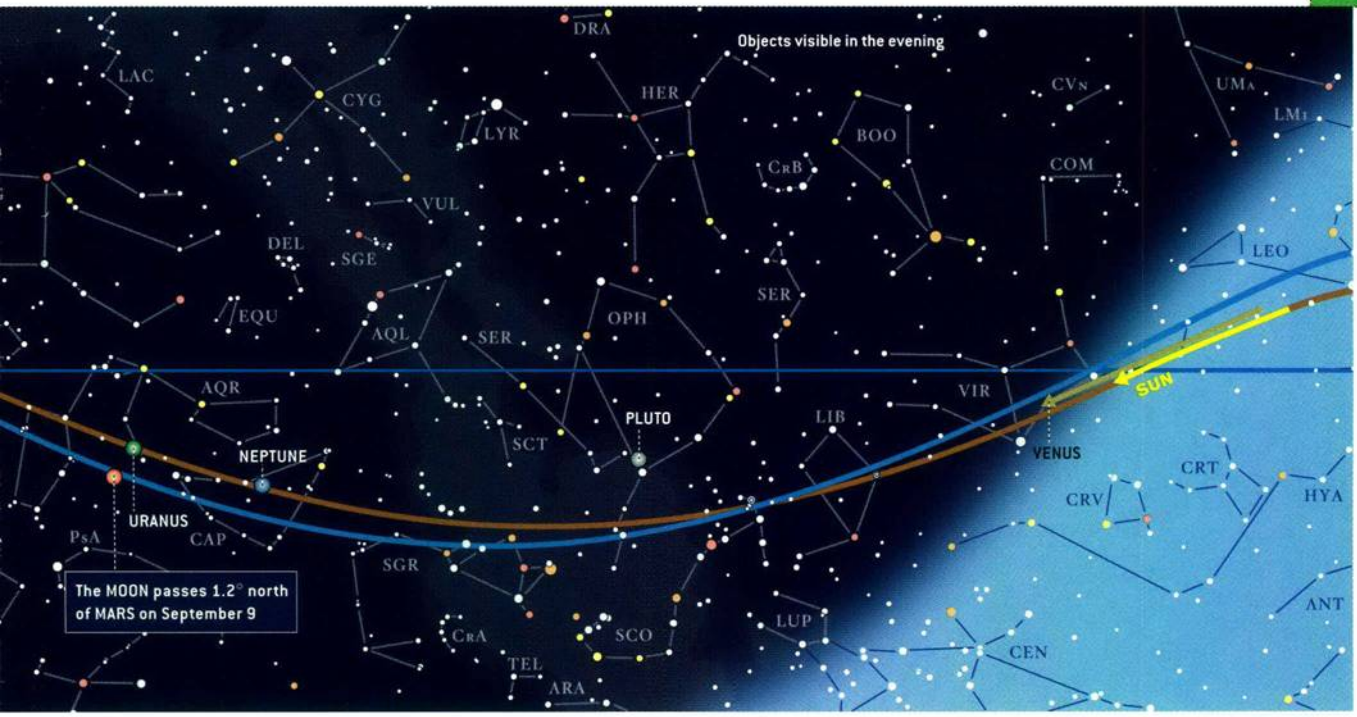
PLANETS	MERCURY	MERCURY	VENUS	MARS
Date	September 1	September 30	September 30	September 1
Magnitude	1.7	−0.7	−3.9	−2.9
Angular Size	10.0"	6.5"	10.0"	25.0"
Illumination	16%	63%	98%	100%
Distance [AU] from Earth	0.673	1.038	1.676	0.374
Distance [AU] from Sun	0.424	0.310	0.723	1.381
Right Ascension [2000.0]	11h37.3m	11h22.2m	13h07.1m	22h33.8m
Declination [2000.0]	−2°17'	5°42'	−6°03'	−16°04'

Jupiter's moons

Dots display positions of Galilean satellites at 6 A.M. EDT on date shown. South is at top to match the view in a telescope.



uares show motions and locations of solar system objects during the month.


DRA
Objects visible in the evening
LAC
CYG
LYR
HER
BOO
CVN
UMA
LM1
CRB
COM
VUL
DEL
SGE
LEO
SER
EQU
AQL
SER
OPH
SUN
AQR
VIR
PLUTO
LIB
SCT
NEPTUNE
VENUS
CRT
CRV
HYA
URANUS
PsA
CAP
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CRA
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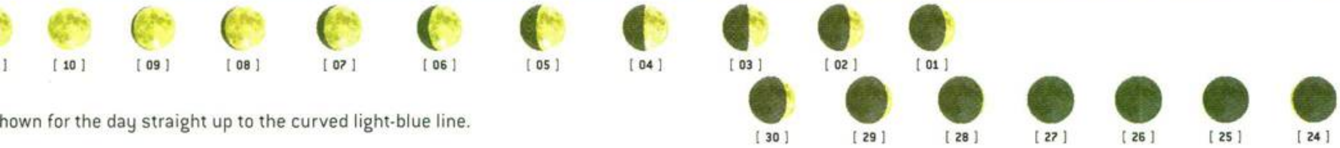
ARA

The MOON passes 1.2° north of MARS on September 9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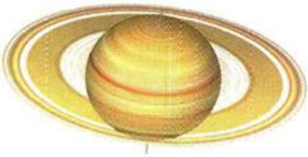
hown for the day straight up to the curved light-blue line.

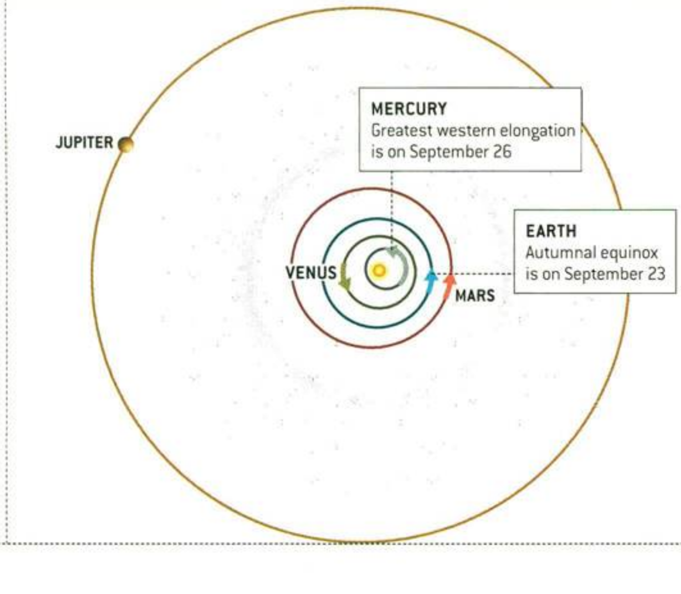


MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
September 30	September 15	September 15	September 15	September 15	September 15
−2.1	−1.7	0.1	5.7	7.9	13.9
20.9"	31.2"	17.8"	3.7"	2.3"	0.1"
95%	100%	100%	100%	100%	100%
0.448	6.328	9.325	19.094	29.311	30.756
1.388	5.379	9.031	20.032	30.078	30.695
22h15.6m	10h24.7m	6h50.6m	22h09.3m	20h52.7m	17h08.2m
−15°46'	10°51'	22°11'	−12°14'	−17°33'	−13°50'

LISTO

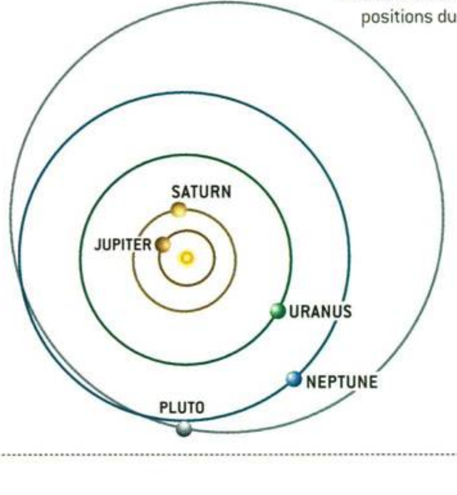
The planets in their orbits

Arrows and dots show planets' positions during the month.


JUPITER
VENUS
MARS

MERCURY
Greatest western elongation is on September 26

EARTH
Autumnal equinox is on September 23


SATURN
JUPITER
URANUS
NEPTUNE
PLUTO

THE DEEP SKY

A variety of observing targets will blow away those cloudy, New Moon blues.

GLOBULAR CLUSTER NGC 7492 in Aquarius is a highly concentrated group of roughly 100,000 stars. PRESTON SCOTT JUSTIS

A watery delight

A common complaint of deep-sky observers is that New Moon weekends often seem to be cloudy. But astronomy is all about taking time at the eyepiece and relaxing. Most people get more out of observing when they aim for a frequent state of contentment than rare moments of exhilaration at the edge of detection.

The biggest challenge you face is not sliding along tendrils of nebulosity or splitting lensed quasars, but finding something interesting night after night, regardless of the Moon's brightness or an otherwise light-polluted sky. If you're a hard-core, faint-fuzzy observer, it's not easy to change your mindset. But it's worth it. Just set up your scope in the backyard, and within a couple of nights, you'll break the mold you've put yourself in.

While you're letting your scope cool down, point your binoculars at Tau¹ (τ¹) and Tau² (τ²) Aquarii, a field to the left (east) of blazing Mars. You could slide a Full Moon between this widely set pair. The brighter one, Tau², glows a nice pale orange. The two stars are unrelated, according to the precise measurements made by the Hipparcos spacecraft.

While you're waiting for the bottom end of the Water Bearer to rise, check out asteroid 84 Klio and Uranus in the middle of the constellation.

Next, hop down to 107 Aquarii and pump up the magnification to split its two modestly bright components, glowing at magnitudes 5.7 and 6.5. Observers disagree on their muted colors; what do you see? Nearby 104 Aquarii also sports a companion.

Not enough color for you? Then slide your scope about one wide-angle eyepiece field south from Omega² (ω²). Burning with a more intense hue is the variable star R Aquarii, a pulsating, red giant variable. Although it will likely be the second brightest object in that area, the real giveaway will be its bright orange color. R Aqr should be near its predicted maximum brightness of about magnitude 6.5, although this enigmatic object once crested at 5.8. Check it out every couple of weeks — no one knows for sure what it will be doing.

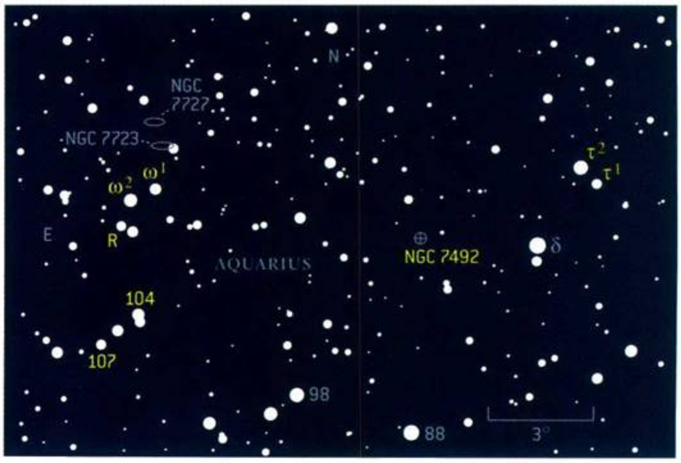
Our eyes and brain are so good at pattern recognition that observers often perceive — correctly — the existence of a new variable star in the field of a known one.

September's weather patterns in the Northern Hemisphere should provide at least a couple of cloud-free opportunities for you to get away from city lights and under rural dark skies.

A star city beckons

A relaxing way to find globular star cluster NGC 7492 is to let Earth do the rotating for you. Center your scope on Delta Aquarii and walk away; come back to it just short of 14 minutes later. The faint, 11.5-magnitude cotton ball will be floating near the middle of your field of view. Just like with faint comets, use an 8-inch scope at about 100x with a dark hood over your head to enhance the pale glow. You won't resolve any of its stars, so it will look a bit like an elliptical galaxy.

Compare NGC 7492 with a pair of galaxies, NGC 7723 and NGC 7727, located 2° north of Omega¹ (ω¹). Both should be a bit brighter and show brighter cores than the globular.



Martin Ratcliffe *is former president of the International Planetarium Society.* **Alister Ling** *is a meteorologist with Environment Canada.*

THE PLANETS

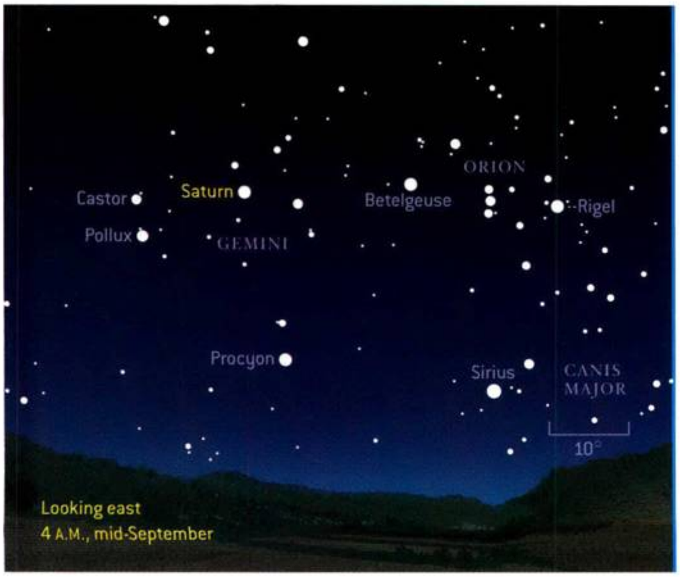
The trio of Mars, Uranus, and Neptune remain the planetary highlights, but Saturn makes a splendid morning return.

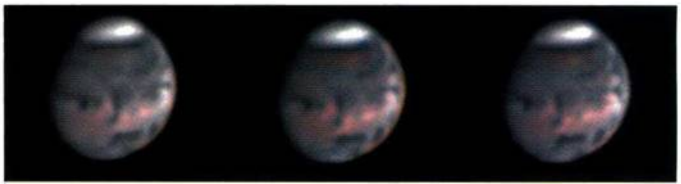
September begins with Mars, close on the heels of its August 28 opposition, continuing its best appearance in centuries. Take advantage of its brilliance now. Within weeks, Mars and Earth will be receding rapidly from one another and Mars will appear to shrink. Uranus and Neptune join Mars as worthy evening targets.

Meanwhile, Mercury makes a brief appearance in the morning sky joined by Jupiter, whose reappearance from behind the Sun generates a brief appetizer for observing the giant planet later in the year. Saturn fills the morning planetary viewing menu admirably, rising by midnight at the end of the month.

Our evening planet viewing begins as soon as the sky darkens after sunset. **Mars** stands low in the southeast an hour after sunset in early September. Shining at magnitude –2.9, it easily ranks as the brightest object in the sky aside from the Moon. By midnight, it stands almost due south. During the first week of September, its disk remains 25" in diameter, roughly equivalent to the well-known crater Eratosthenes on the Moon. The Moon joins Mars in the evening sky, reaching First Quarter phase on September 3 and passing less than 5° west of Mars on the American evening of September 8. Before Mars sets some hours later, the gap shrinks to less than 3°.

Inspect the position of Mars against the background stars of southern Aquarius during the month and note it in your observing log. As September progresses, Mars appears to move closer to Delta (δ) Capricorni, although it never quite reaches the star.





MARS REMAINS A GREAT TARGET throughout September. All month it appears more than twice the size it did when these photos were taken in mid-May. DONALD C. PARKER

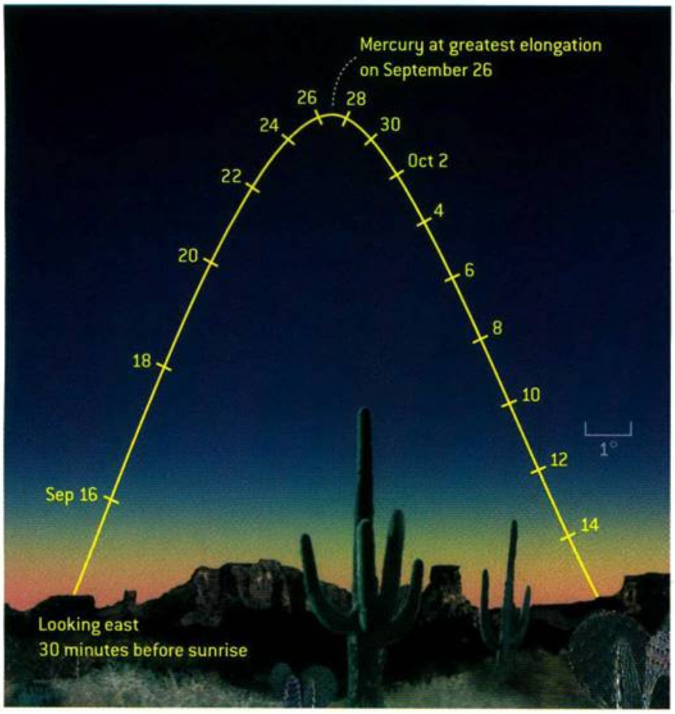
The planet's retrograde, or westward, track slows to a halt on September 29 when Mars stands less than 4° away from another planet, the significantly more distant, and intrinsically larger, Uranus. Following the westerly halt, Mars returns to its normal, easterly path. This retrograde loop results from Earth passing the Red Planet as the two orbit the Sun. Like two cars speeding around a racetrack, Earth moves faster in its inner orbit and Mars appears to fall back as we charge ahead.

By September's end, Mars has dimmed to magnitude –2.1 and spans 21". Mars still appears better than during its previous opposition in 2001, but the opportunity to view the Red Planet at a large size will end shortly.

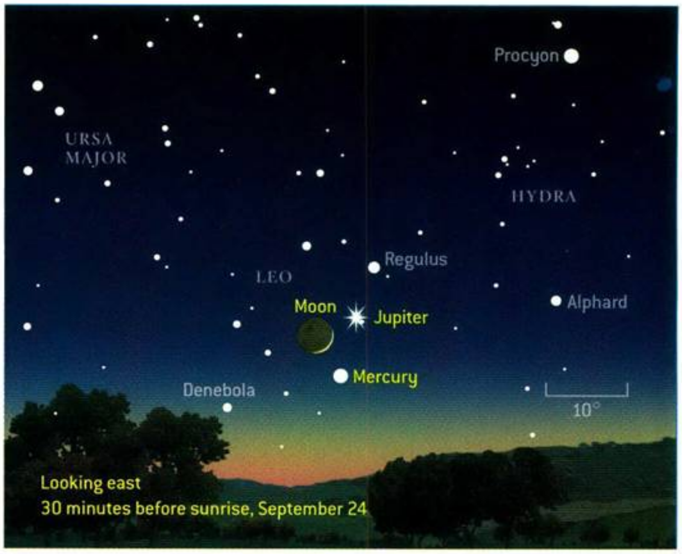
During the course of a single night, almost half the planet rotates in front of you. The rotation period of Mars is some 37 minutes longer than Earth's, resulting in nearly the same features being visible from one night to the next. Yet over the four weeks of September, a significant portion of the planet comes into view for anyone who views at the same time each night.

Uranus can never compete with Mars, but a chance to see the seventh planet from the Sun occurs each night that Mars is visible. Near the end of September, Uranus lies northwest of Mars. Uranus is some 50 times farther from Earth than Mars and would, if it were the same size as Mars, shine 2,500 times fainter (50 times 50, a result of an object's brightness dropping as the square of its distance). Uranus, however, is seven times larger than Mars, and so the brightness difference is only 1,500 times, making Uranus about eight magnitudes fainter. The gas giant shines at magnitude 5.7, which makes it visible in binoculars if you know exactly where to look. (It can be glimpsed, barely, with the naked eye under exceptional conditions.) A telescope reveals the tiny disk of Uranus, which spans only 3.7", or about one-sixth the size of Mars.

If you have been staring at Mars through a telescope for an hour or so, try a little *experiment* and swing over to Uranus. The colors of astro-



Looking east
30 minutes before sunrise



Looking east
30 minutes before sunrise, September 24

nomical objects are very subjective and strongly influenced by local circumstances. Uranus typically shows a soft blue-green hue. But what does Uranus look like after observing a bright orange-red planet? Perhaps it has a stronger cast. You can pick up the distant giant planet near the 5.4-magnitude star, 38 Aquarii. Using 7x50 binoculars, Uranus stands approximately one field of view northwest of Mars.

Neptune, the next planet in order of distance from the Sun after Uranus, lies farther west in central Capricornus. It is well placed for viewing while you wait for Mars to rise above the haze and turbulence that builds up on a September day. Neptune is much dimmer than Uranus, shining at magnitude 7.9, and lies at a distance of 2.7 billion miles. To find Neptune, begin with Theta (θ) Capricorni, a 4th-magnitude star that stands in the middle of the upper portion of Capricornus. Within the same field of view of 7x50 binoculars, look for a trio of objects. The two lower stars are brighter and the upper, fainter member of the triangle is Neptune. They form an equilateral triangle at the end of September.

Saturn rises around 2 A.M. local daylight time in the northeastern sky in early September, and it clears the eastern horizon by midnight at month's end. It shines at magnitude 0.1 among the background stars of Gemini the Twins. The eastern sky is full of brilliant winter stars during September mornings, a reminder of the cold weather about to settle over the land. Yet only Sirius, the Dog Star, outshines Saturn, at least until Jupiter rises just before dawn.

Jupiter comes up in dawn's first light among the stars of Leo the Lion. Regulus, Leo's brightest star, rises 30 minutes earlier, heralding the arrival of the giant planet. Jupiter shines at magnitude –1.7, some five times brighter than Saturn. A telescope offers a fine view of Jupiter's four major moons: Io, Europa, Ganymede, and Callisto, in order of their distance from Jupiter. Following a cool night, our atmosphere is often steady, perhaps offering telescopic observers a brief but fine view of some features in the jovian atmosphere.

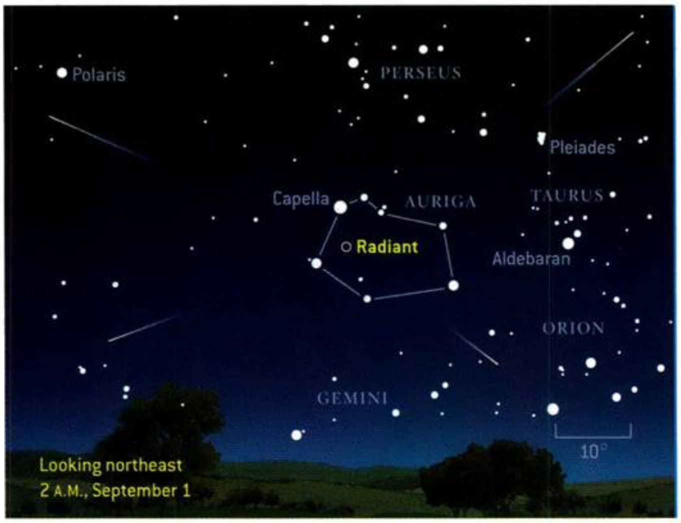
Survey the eastern sky on the morning of September 24 for a wonderful view of a slender crescent Moon together with Mercury and Jupiter. Mercury shines at magnitude 0.0. The best view occurs roughly between 60 and 45 minutes before sunrise; after that, the quickly brightening sky will cause the spectacle to melt with the daylight. The three objects lie within 7° of each other.

Mercury reaches its greatest elongation on September 26, when it lies nearly 18° west of the Sun. This is not the farthest Mercury can get. It can reach 27° away from the Sun, but it is held back this month because it reaches perihelion (the closest position in its orbit to the Sun) on September 27. Still, because the ecliptic makes a steep angle to the eastern horizon on autumn mornings, Mercury puts on a good show.

Earth reaches a point in its orbit where its axis angles neither toward nor away from the Sun, but at just the right position to give equal illumination to the Northern and Southern Hemispheres. Such a situation occurs twice a year and results in 12 hours of day and night over the entire Earth. This is the autumnal equinox. For astronomers watching the Sun parade along the ecliptic, the Sun appears in the sky at the point where it crosses the celestial equator heading north to south at exactly 6:47 A.M. EDT on the 23rd.

METEORS AND MOONS

Despite a dearth of prominent meteor showers, early September may provide a brief surprise. An ancient lunar crater that shows plenty of detail appears clearly both early and late in the month.



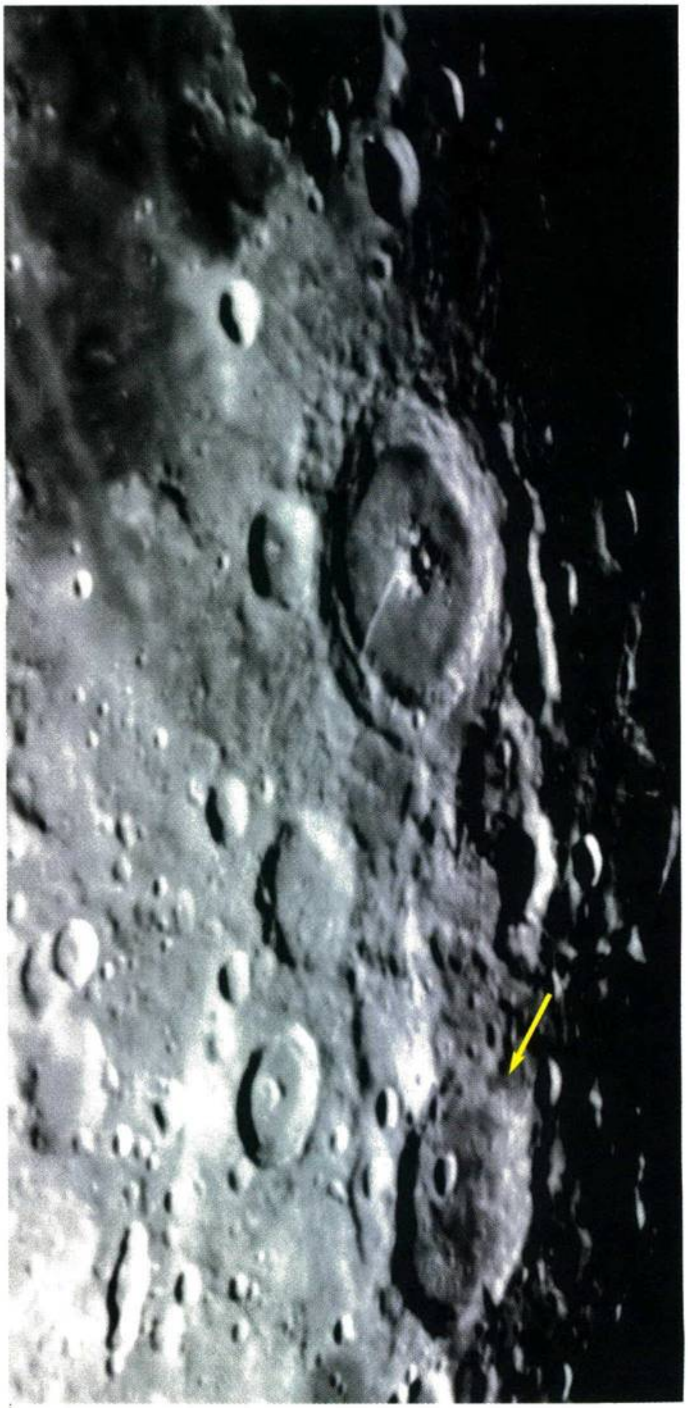
Capella's meteors

Sporadic meteors abound in September, although there are far fewer meteors visible than under the rich August skies. Nevertheless, one shower of note peaks on September 1, although the word "peak" may give a false impression. A handful of observers noticed strong returns for the Alpha Aurigids in 1986 and 1994, reaching a zenithal hourly rate (ZHR) of approximately 30 meteors per hour. (The ZHR, is calculated from the observed rate adjusted for the altitude of the radiant and the darkness of the sky.) Typical rates for this shower are near the sporadic background rate of seven per hour, but all meteor trails trace back to a radiant near Capella in Auriga. The crescent Moon sets in mid-evening, offering meteor observers a favorable opportunity to observe and record this little-noticed, but nonetheless impressive shower.

The crater Furnerius

On the southeastern limb of the Moon, south of Mare Crisium, lies the 78-mile-wide crater Furnerius. It appears to be part of a chain of craters that includes Petavius and Langrenus. Furnerius is old, indicated by the secondary craters on its floor. The prominent Furnerius B is 13 miles wide, but smaller craters litter the floor and others degrade the walls.

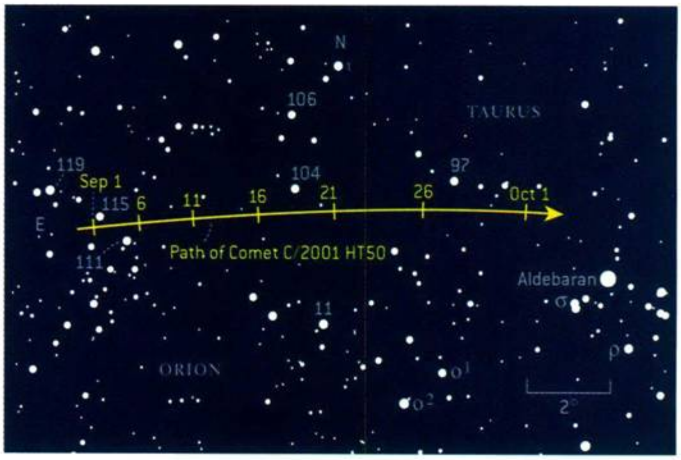
A variety of different terrains occupy the floor of Furnerius. Smooth areas are evidence of more recent flooding by lava, while rough and hilly regions occupying more than 80 percent of the floor indicate an older age. See if you can spot any of these, and record your observations with a simple sketch. You can catch sunrise over the crater as soon as the crescent Moon appears after New Moon; sunset occurs the day after Full Moon.

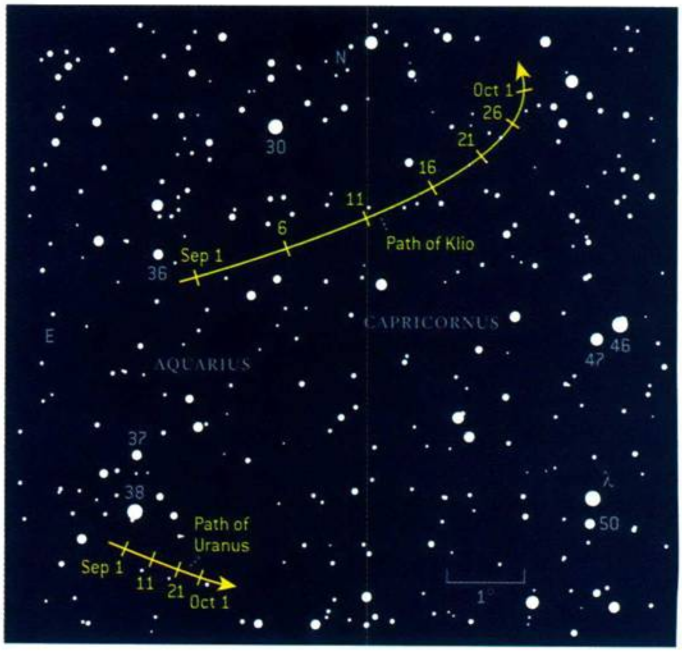


THE LUNAR CRATERS Furnerius (arrow) and Petavius (top) form an attractive pair a day or two after both New Moon and Full Moon. LEE C. COOMBS

COMETS AND ASTEROIDS

We are currently in a lull before a storm of snowballs, so it's going to get better in the months to come.





HT50 leads the pack

Later this fall, Comet 2P/Encke will brighten into binocular range, and next spring we have two potentially naked-eye comets. In contrast, to see comets this month is to pass a dark-sky challenge. The current crop of faint fuzzballs requires an 8-inch telescope, an accurate starchart, and some patience if you're new to comet tracking.

The leader of the pack is Comet C/2001 HT50 (LINEAR-NEAT), which was actually co-discovered by three robotic near-Earth asteroid search programs: LINEAR, NEAT, and LONEOS. Your best view of this primordial, dirty snowball comes near dawn, in the first and last week of the month when the Moon's distracting glow will be out of the morning sky.

A full magnitude dimmer than the faintest of the Messier nebulae and galaxies, this comet glides through the star fields of southern Taurus. Few galaxies reside here — the Milky Way's dust effectively blocks most of them from view — so you shouldn't confuse the interplanetary interloper with a deep-sky object. C/2001 HT50 remains beyond the grasp of binoculars because its orbit never brings it any closer to Earth than the main asteroid belt.

Make sure you use the experienced observer's wisdom to find the comet: Use a dim red light and drape a dark cloth or hood over your head to keep out stray light. Remember to nudge the power up past 100x to help cajole the comet's soft glow out of the background. Speaking of nudging, a gentle tapping on the scope can bring success because peripheral vision is very sensitive to motion.

This advice will be even more important for the fainter comets: 65P/Gunn hovers in Sagittarius during the evening hours and C/2002 T7 (LINEAR) trails in Auriga near M36. Charts for these two are available at www.astronomy.com; click on *hobby news*. Astronomers forecast C/2002 T7 to reach 1st magnitude next May.

A rocky Klio

As if mimicking the comets, no bright asteroids grace our skies this month either. However, well placed in Aquarius along with several deep-sky objects and the planet Uranus is Klio, the 84th asteroid to be discovered.

Any small telescope will reveal the lovely aquamarine disk of the planet, which serves as a stepping stone to Klio. Slide 4° north of Uranus (a bit less than a standard binocular field) and you'll be just west of the next guidepost star, Theta (θ) Capricorni. Next, use the close-up chart (above right) to hop over to 84 Klio's position.

Spiral galaxies like the Milky Way have a bulge of stars around their core. When we look toward Aquarius, we are peering toward the outer fringes of this core. All those faint stars will make Klio, at magnitude 10.6, harder to find than our usual asteroidal fare. Sketch the star field fainter than what's shown on the chart and come back a few nights later to see which of the "stars" has changed position.

German astronomer Richard Luther discovered Klio on August 25, 1865. With a diameter of 50 miles (80 km), Klio is less than one-fifth the size of the biggest asteroids, which explains why it doesn't glow very brightly. ◼

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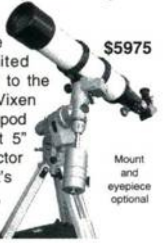

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Celestron NexStar 11 GPS

a $2999 value, to be given away *free!*

CELESTRON

The review said the scope had "brains and good looks. The NexStar 11 GPS puts Celestron's time-tested 11-inch f/10 Schmidt-Cassegrain optics in a sleek new package that includes some of the most advanced electronics ever offered in a mass-produced telescope . . . Celestron is the first to take Go To scopes to the next step in their evolution, and it's a nice step indeed."

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Discovery 8" f/8 Marscope Dobsonian

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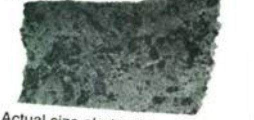
SaU 005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Searching digital skies

Astronomy enters a new electronic era as data go on-line and scientists make discoveries using mammoth virtual observatories. /// BY STEVE NADIS

THROUGHOUT THE WORLD, SCATTERED ON MOUNTAINTOPS AND IN academic centers, astronomical data sleep. Archived and available for the asking, these data await an interface that makes easy access possible for astronomers everywhere. Soon, we've been promised, the International Virtual Observatory (IVO) will be this interface. Combining data from the world's biggest ground- and space-based observatories, it will ultimately provide complete views of the sky in 15 wavelengths through coordinated databases via the Internet.

The IVO will link the United States's National Virtual Observatory (NVO) with Europe's Astrophysical Virtual Observatory (AVO) and other components spread across the globe to form a network that affords unprecedented access to astronomical data. The AVO had "first light" January 20, 2003. The NVO is still under development. More than just a data-collating exercise, the IVO is intended to support a new kind of science — a statistical-based approach that combs through unimaginably large data sets, seamlessly merging multiple-wavelength perspectives into one view of the sky.

Alex Szalay of Johns Hopkins University, the lead U.S. astronomer on the project, is confident virtual observatories (VOs) "will change astronomy as we know it today." He wants to free astronomers from "mindless tasks"— collating, reformatting, and searching for data — so they can focus on science. This won't lead to closing telescopes, he insists, but it should reduce the number of observations repeated because people didn't know data existed. New statistical techniques will emerge when astronomers can sift through billions of objects, looking for "outliers" that smaller samples may miss.

"By early 2004, I expect people can start using this for real, at least for simple things," says Szalay. "We want to create a building block for the future — a lot of little pieces that interconnect rather than one big monster."

The potential of such a system is substantial. Already, scientists are plugging into virtual databases, sometimes using clunky interfaces distributed across multiple web sites. Their early results clearly demonstrate that virtual data acquisition streamlines research and facilitates scientific inquiry — even for investigators who lack access to major telescopes. These preliminary successes provide a glimpse of what's to come when the IVO becomes a reality.

Small school, big science

As an astronomer at the Carnegie Observatories and a member of the Las Campanas survey team in the mid-1990s, Stephen Landy knows what big-time astronomy is all about. But now that Landy is a physics professor at a small school, the College of William and Mary in Williamsburg, Virginia, his research horizons are different. His main interest is cosmology, and he acknowledges many of the key questions in the field cannot be answered from small data samples. "You need large data sets like the Sloan Digital Sky Survey to take on the biggest questions," he says. "For someone at a small college with a primary emphasis on teaching, it's really hard to be a member of the big teams."

So Landy relies heavily on publicly available data. In a 2002 paper published in *Astrophysical Journal Letters*, he drew on data from three of the largest galaxy redshift surveys: the

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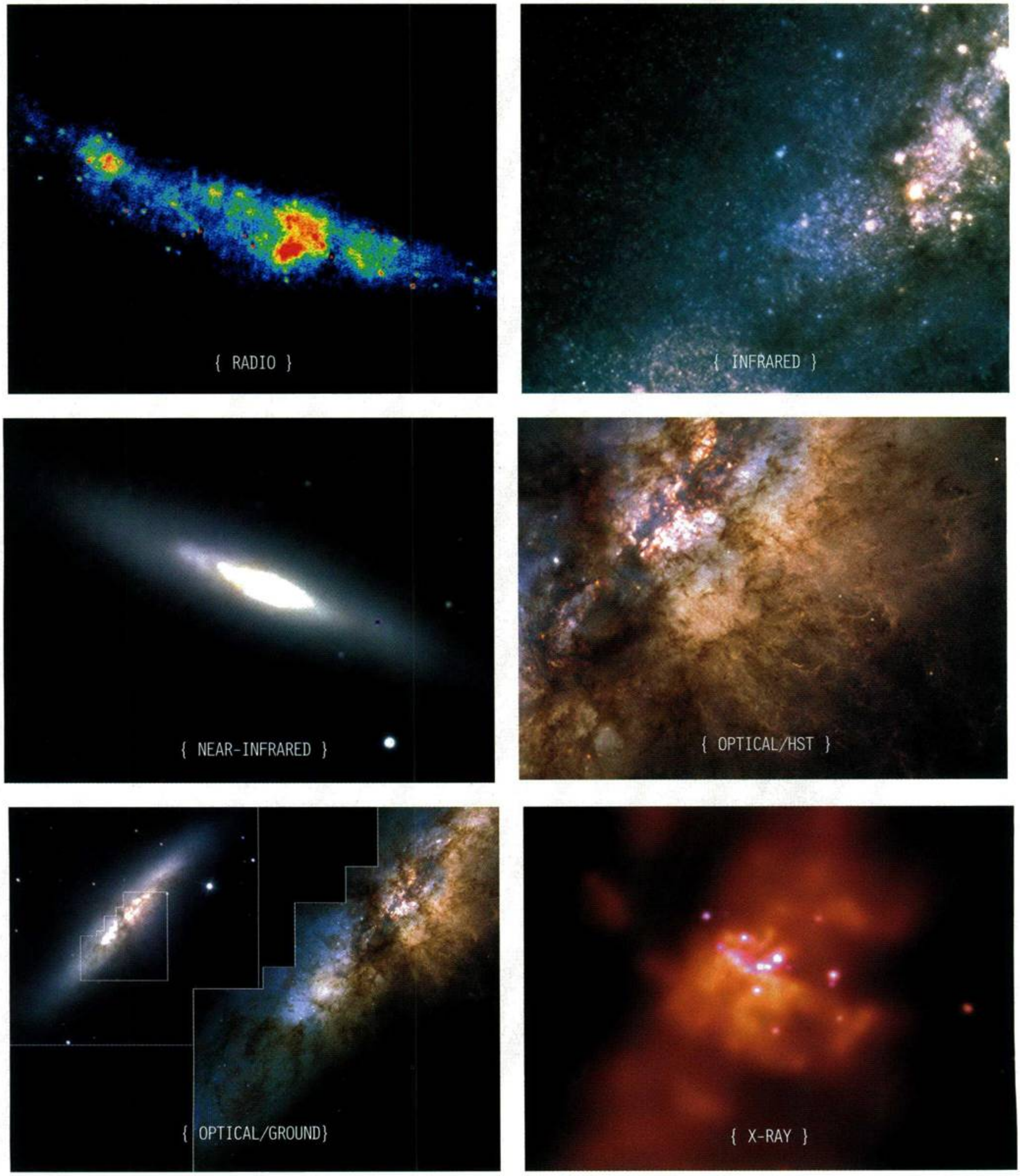


EASY ACCESS TO MULTI-WAVELENGTH DATA will expedite research. Eliminating the all too frequent duplication of observations, the International Virtual Observatory will bring data from x-ray satellites, radio dishes, and other resources together in a single location. In the future, all these images of the starburst galaxy M82 might pop up with a few clicks of a mouse. Currently, obtaining these science images requires searching four web sites and making at least one phone call.

RADIO: TOM MUXLOW, ALAN PEDLAR, KAREN WILLS AND PETER WILKINSON/VLA/MERLIN /// INFRARED: NASA, ESA AND R. DE GRIJS (INST. OF ASTRONOMY, CAMBRIDGE, UK) /// NEAR-INFRARED: 2MASS /// OPTICAL/HST: NASA, ESA AND R. DE GRIJS (INST. OF ASTRONOMY, CAMBRIDGE, UK) /// OPTICAL/GROUND: N.A. SHARP/AURA/NOAO/NSF /// X-RAY: NASA/CXC/SAO/PSU/CMU

Sloan Digital Sky Survey (SDSS), the Two-degree Field (2dF) galaxy redshift survey, and the Las Campanas redshift survey. Using redshifts available for over 120,000 galaxies, Landy studied how galaxies move relative to one another. These interactions are related to the overall density of matter, and he showed that the mass density of the modern universe corresponds to measurements based on the much older cosmic microwave background.

The prospects for studies like Landy's should get better in the future, he says. "There's a huge amount of data that's begging for people to analyze it. You can't expect project scientists to do all the research that could possibly be done with the data." Once the virtual observatory is up and running, astronomers will become even more productive. Landy adds, "I'll have the same access to information as people at more research-focused institutions." With a level playing field, the sky literally is the limit.

Where the data lie

Life was different for Chris Churchill when he was a graduate student at the University of California, Santa Cruz. He made regular trips to the Keck Observatory in Hawaii, home to the two largest optical telescopes in the world. Now that he's joined the faculty of Pennsylvania State University, Churchill no longer has observing privileges at Keck and can't continue his survey of quasar spectra on those telescopes. "I could go to Gemini, but I'd be lucky to get one night per year, and you can't do a survey that way." Desperate to find something to do, he "went where the data was." From 1999 to 2001, he published about twenty papers that combined archival data from the Hubble Space Telescope with the data that he obtained from Keck. "I don't think I've written a paper where I haven't first checked the Hubble archive to see what the Space Telescope has done."

Churchill studies quasar absorption lines; he's less interested in the quasars themselves than in the gas clouds they illuminate. The atoms in the gas interact with quasar light, leaving distinct fingerprints in the form of atomic absorption lines, providing information about the chemical composition of the clouds.

"This study is just a hint of what might happen with the NVO," says Churchill. When that facility is in full swing, he could do an entire quasar "survey" without having to apply for telescope time. "Each object might have been observed for a separate scientific reason. Then someone else comes along with a different question that the original astronomers never dreamed of investigating. That, to me, is the beauty of the NVO."

Taking aim at distant clusters

Brian McNamara of Ohio University in Athens, Ohio, is interested in evolution, but unlike Charles Darwin who studied living creatures, McNamara focuses on the evolution of galaxy clusters. He and his colleagues suspected that faint x-ray sources might be associated with galaxy clusters. To test this hypothesis, they wrote a computer program to sift through the archives of ROSAT (an orbital x-ray observatory that operated from 1990 to 1999) and look for extremely faint splotches of x-ray emissions. Optical observations of these splotches made with the Multiple Mirror Telescope in Arizona and other facilities confirmed their hunch.

Studying clusters at a variety of distances from Earth, the team showed there were fewer luminous clusters in the past, "when the universe was younger and things had less time to grow," McNamara explains. Because light has a finite velocity, distant objects appear as they did when the universe was younger. This finding supports the notion that big cosmic entities like galaxy clusters grew from smaller parts — a so-called "bottom up" view of structure formation.

"This is exactly the kind of work that would benefit from a virtual observatory," McNamara says. Many of the x-ray sources he and his team observed may lurk in other observers' data and in archives that aren't on-line. "We could have cut out 80 percent of our observing time and just gone to a big telescope to get redshifts of the most distant objects. There's no doubt the NVO will be a tremendous asset."

Political astronomy 101

For those innocent souls who consider astronomy a pure science removed from the realm of politics, think again, says Frazer N. Owen of the National Radio Astronomy Observatory in Socorro, New Mexico. "Getting telescope time and all the data you want can be a complicated process, involving lots of negotiation." To gain access to the Gemini telescope, for instance, a team of collaborators may write several different proposals for several different time allocation committees. When it comes to sharing data, Owen adds, "sometimes you have to contact people you don't know, ask for their data, and convince them yours may be useful to them as well. If you don't have anything to trade, you may be out of luck. People are usually cooperative, but occasionally you reach an impasse."

As an example, he cites a paper he coauthored last year in *Astrophysical Journal Letters*. While looking at distant clusters with a radio telescope, he found out that a British team was observing the same field in submillimeter wavelengths. "We negotiated with them to combine the two data sets and learned that most of the submillimeter sources were also radio sources." After determining the position of the most powerful source of submillimeter radiation from radio measurements, the group went to Gemini and identified the object as an active galactic nucleus, which surprised everyone. "When you see things in submillimeter, one normally believes you're seeing dust heated by star formation," Owen notes. "Now we have to consider the possibility that an active galactic nucleus heated the dust."

Due to this chance collaboration, Owen and his colleagues ended up studying something far different than they'd originally

> **NED is immensely popular.** The web site averages 2 million hits per month – a number that has doubled every 18 months for the past decade.

planned. Still, he longs for the day when information is more readily available on the web, so he can spend less time politicking and bartering. If plans for the virtual observatory are on track, that day may be close at hand.

Radio skies

To catch a glimpse of what a virtual observatory might offer, check out the NVSS database (www.cv.nrao.edu/nvss/) and then multiply by 15 wavelengths; NVSS is shorthand for the NRAO (National Radio Astronomy Observatory) VLA (Very Large Array) Sky Survey, which was completed in 1998. This survey cataloged more than 1.8 million radio sources in the northern sky. It consumed 2,500 hours of telescope time. NRAO's Jim Condon, principal investigator for the project, explains that telescope time was granted "with the understanding that as soon as we reduced the data, it would become public. I didn't get to sit on the data and skim the cream, which is okay because there's more than enough to go around."

British astronomers, for example, used the survey to show that the "anisotropy" or asymmetry detected in the cosmic microwave background is evident also in the distribution of radio sources — an effect that astronomers predicted but had not yet observed.

> "For those innocent souls who consider astronomy a pure science removed from the realm of politics, think again" – FRAZER OWEN, NRAO

Franz Bauer, a former University of Virginia graduate student, wrote a thesis in 2001 identifying what types of galaxies account for most of the universe's x-ray sources. Starting with the ROSAT survey, Bauer used NVSS to identify radio sources associated with x-ray emission. With accurate positions from the radio data in hand, he went to Kitt Peak National Observatory to optically probe sources identified in x-ray and radio surveys. He discovered that most were Seyfert galaxies, with a few quasars thrown in.

"With the virtual observatory, Bauer still would have gone to Kitt Peak, but he could have knocked off the identifications in a day, rather than a year," Condon says. "Today you have to write a bunch of computer programs to correlate the x-ray, radio, and optical data, but soon that will be handled automatically." Lots of things that are easy now were a struggle years ago, he adds. "Thinking of all the months I spent on tasks that take hours today doesn't bother me at all. That's progress."

Handle with care

Chuck Steidel is not the target audience for a virtual observatory. As an astronomer at Caltech in Pasadena, Steidel considers himself, "lucky to have access to large telescopes like Keck." He takes advantage of this position and makes his own observations, mainly in the optical and near-infrared bands. When he used archival data from Chandra in two studies published last year, he collaborated with an x-ray astronomer who understood the data well. "I feel nervous reducing someone else's data without knowing exactly how it was processed," he admits. "That's why I worked with someone who knew just what to do with it."

While surveying distant galaxies with Keck, Steidel wanted to know about the x-ray properties of intense star-forming regions. X rays provide a "cleaner" view of such zones because dust interferes less with x-ray light than with optical light. Estimates of star formation rates depend on estimates of dust extinction, and the x-ray data convinced Steidel "we weren't barking up the wrong tree. Although we didn't learn anything terribly new by taking this independent look, it still adds to one's confidence."

The virtual observatory will make multi-wavelength work like this easier, but there's one thing that still worries Steidel. "When data is handed to people on a platter, they often don't understand it as well as they should," he says. "By making it easier to get other people's data, will we make it easier for data to be misused?"

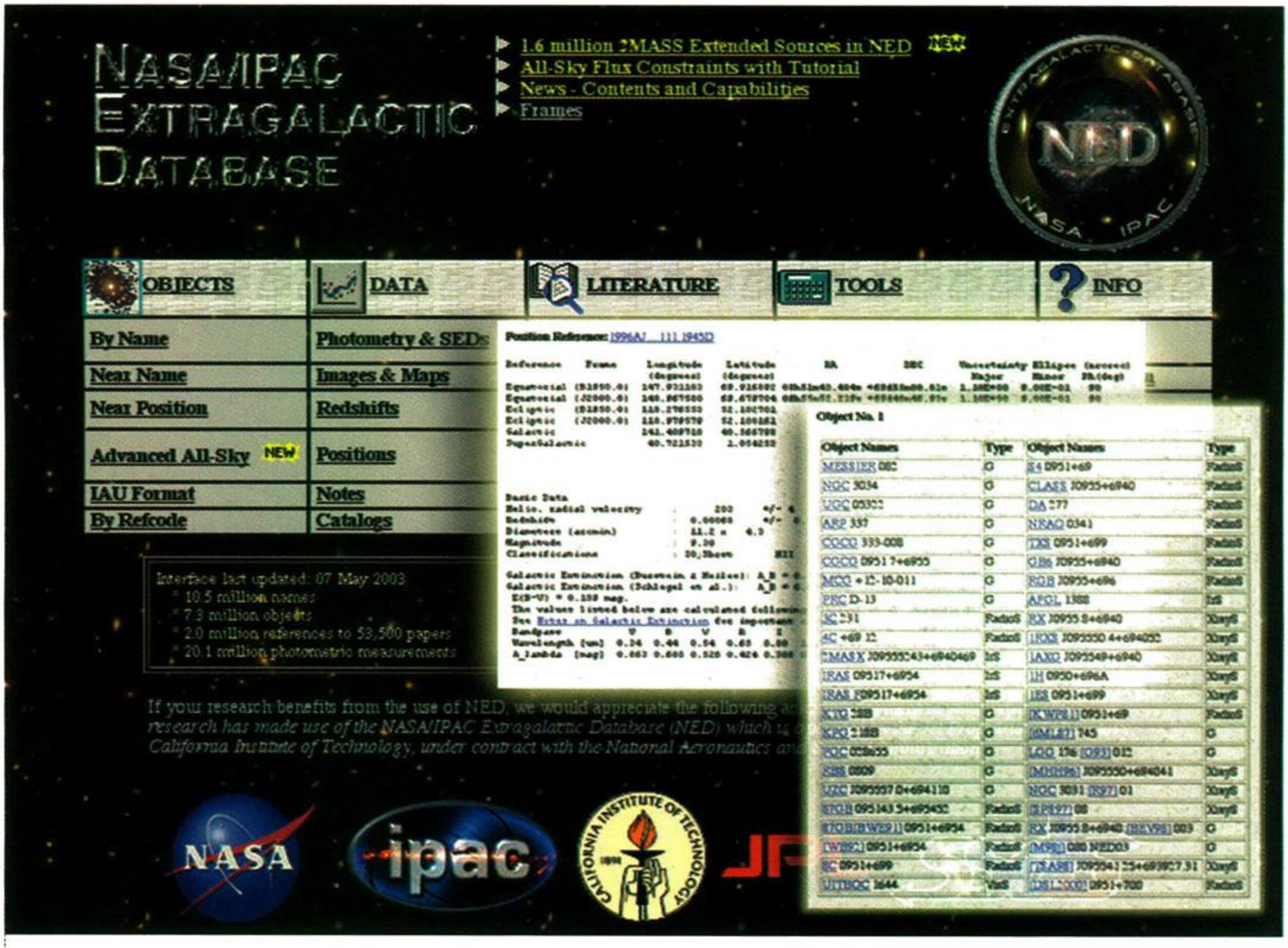
NED: The soul of the new machine?

If you want "the closest thing to a virtual observatory that exists today," Condon says, you ought to meet NED — the NASA/IPAC Extragalactic Database. The NED web site (nedwww.ipac.caltech.edu) lists the names and positions of more than 6 million galaxies and provides links to all known data and published literature related to each object. With a few clicks of the mouse, says Barry Madore, the Caltech astronomer who co-directs the project, "NED brings up the full view of human knowledge on a given object."

The tool is immensely popular. The web site averages 2 million hits per month — a number that has doubled every 18 months for the past decade. "Every day there's a new paper in a peer-review journal that cites NED," says Madore. "Almost every graduate student in extragalactic astronomy uses NED daily."

Madore uses it himself. In a 2003 paper he wrote with Gregory Bothun of Oregon University and Wendy Freedman of Carnegie Observatories, Madore revisited work done by Bothun. About 20 years ago, Bothun spent months poring over photographic prints with a magnifying glass, trying unsuccessfully to find companions to elliptical galaxies. With NED at his disposal, Madore redid Bothun's analysis in an afternoon. Not only did he find companions, he also charted their radial and orbital velocities as a function of radius — thereby providing quantitative pictures of the dark matter surrounding galaxies.

Madore is convinced NED can do more than save astronomers time. He thinks the idea could be expanded to form the core of the International Virtual Observatory — a point he argued in a paper presented to NASA in 2003. His plan calls for an on-line master directory — a point of entry to the collective store of astronomical knowledge. The directory would send people to NED for information on galaxies, to SIMBAD (a complementary site created by French astronomers that lists more than 3 million objects) for stars, to the Hubble *Space Telescope* site for images, to Chandra for x-ray data, and so forth. "It's not possible to bring all the information to a central place, but you can bring a token,"



NASA/IPAC EXTRAGALACTIC DATABASE

- 1.6 million 2MASS Extended Sources in NED NEW
- All-Sky Flux Constraints with Tutorial
- News - Contents and Capabilities
- Frames

OBJECTS	DATA
By Name	Photometry & SEDs
Near Name	Images & Maps
Near Position	Redshifts
Advanced All-Sky NEW	Positions
IAU Format	Notes
By Refcode	Catalogs

Interface last updated: 07 May 2003
- 10.5 million names
- 7.3 million objects
- 2.0 million references to 53,500 papers
- 20.1 million photometric measurements

If your research benefits from the use of NED, we would appreciate the following a
research has made use of the NASA/IPAC Extragalactic Database (NED) which is o
California Institute of Technology, under contract with the National Aeronautics an

NED IS A CLOSE FRIEND to every graduate student and most professionals working in galactic astronomy. The NASA/IPAC Extragalactic Database contains references both to papers and images, all cross-referenced by names and positions. An on-line gateway that allows researchers easy access to past observations, the system lets astronomers explore new scientific ideas without necessarily requesting telescope time.

Madore says, "just as you can bring a phone book into your house without inviting all the people."

Madore is not sure how this idea will be received because, computationally speaking, NED is a simple system, and the computer scientists in the IVO project may have something more sophisticated in mind. "We make it look too easy," he says. "To some extent, we've been marginalized by our success."

Making tomorrow happen

Putting aside the hype, where does the virtual observatory stand? The National Science Foundation donated $10 million to the NVO, funding a five-year effort (through 2006) aimed at designing a workable virtual observatory rather than building it in full. Other countries have given about $30 million toward the IVO.

Although the IVO holds undeniable promise, many astronomers outside the project still have qualms. Some researchers, for example, hope the computer scientists building the observatory won't get carried away and forget its true mission. "How many times do we have to remind software people that their packages should be designed to be used by 'plain' scientists and not as challenges for computer freaks?" asks André Heck of the Strasbourg Astronomical Observatory in France. Owen is worried the IVO might accelerate the trend toward large-scale surveys, squeezing out smaller, more focused looks at the sky. Szalay agrees, saying "the virtual observatory is not just for the SDSS. We want to provide easy ways of publishing smaller data sets."

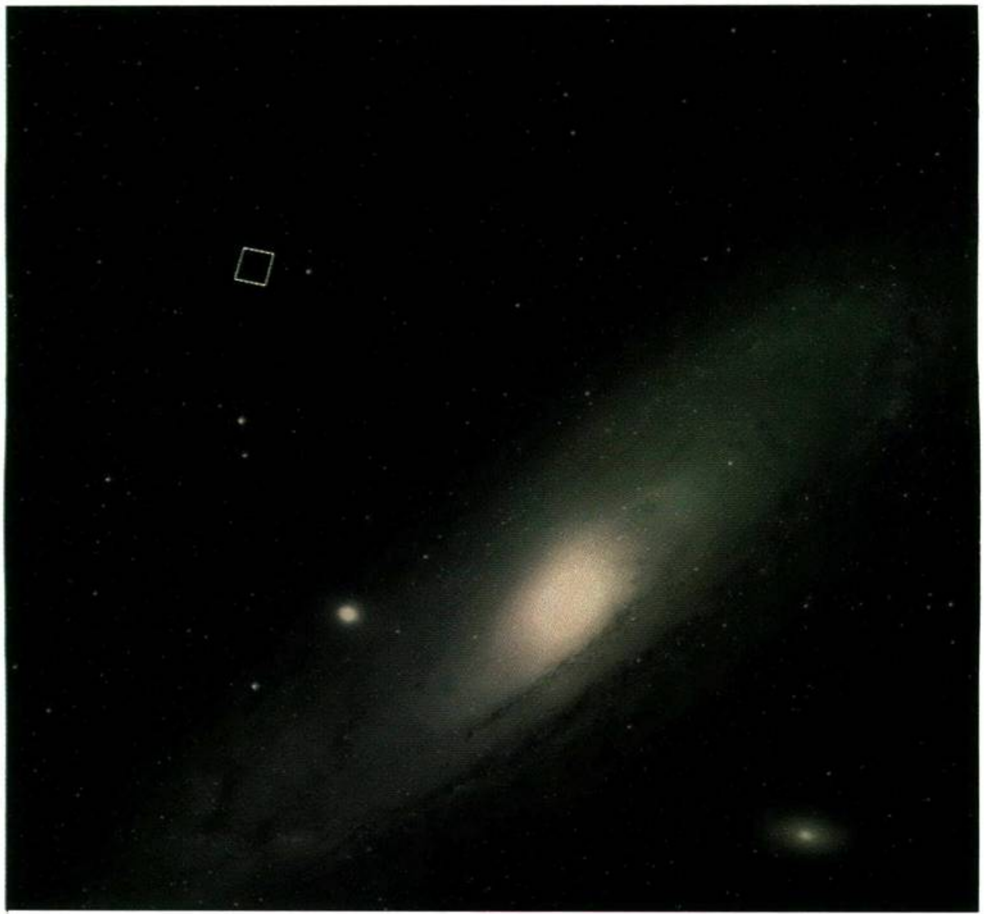
"You can't do it all with surveys," adds Steidel. "Often there are more direct ways of answering questions than the brute force approach of getting all possible data." Steidel also is concerned that astronomers might use data from the IVO without appreciating its limitations. "When it's easy to get data, it becomes easy to make mistakes." Szalay considers the point well taken, noting that the observatory will establish standards for explaining the individual nuances of data sets.

Despite these caveats, Madore believes the "free flow of information" should be paramount. "People can go to telescopes and do bad observing or get data from archives and botch it," he says. "It's unfortunate when that happens, but science is self-correcting. If you don't put something on the web because someone may misinterpret it, you also might prevent people from doing great things." Many astronomers are betting that "great things" are exactly what the virtual observatory will deliver. ■

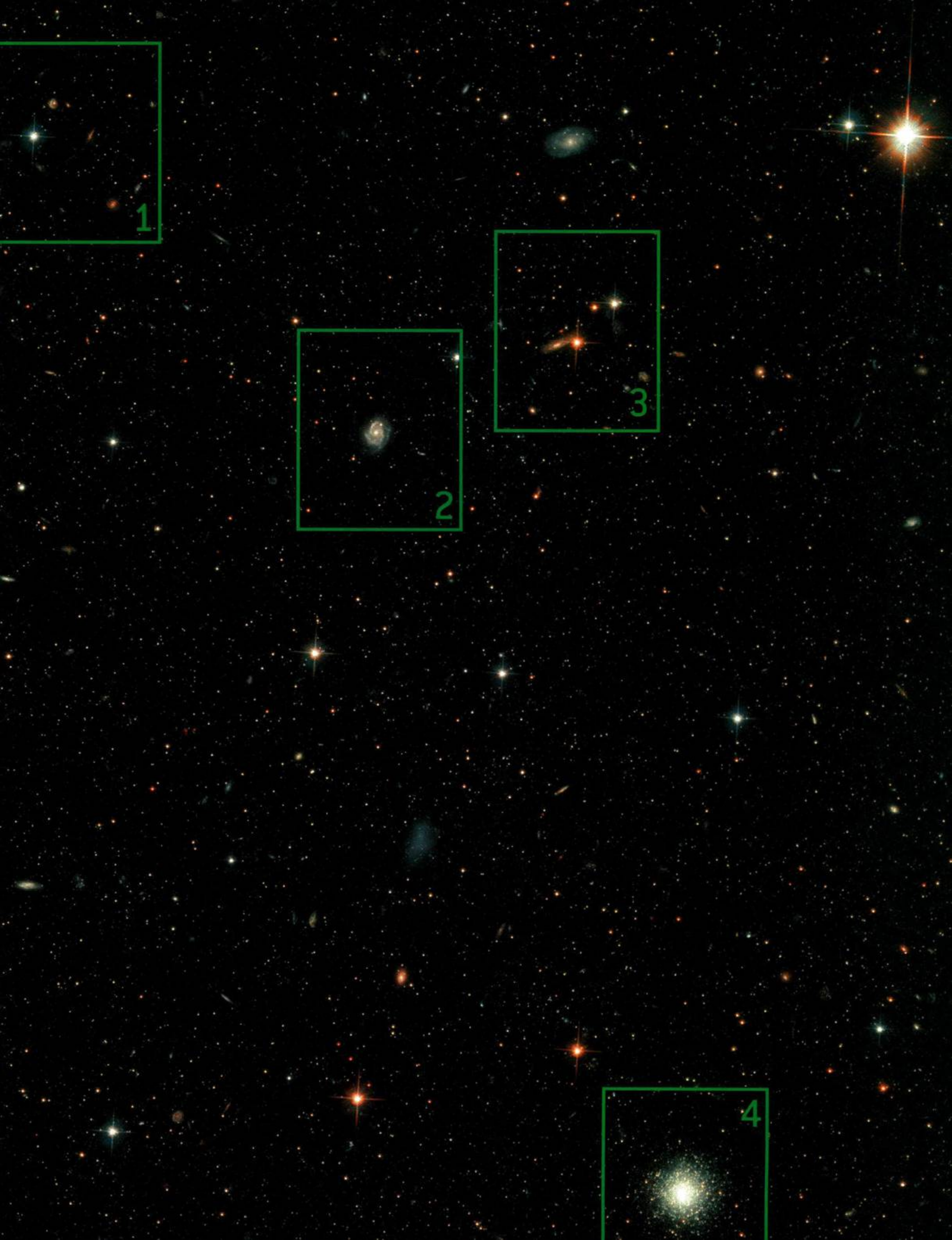
{ EXTRAGALACTIC ASTRONOMY }

Through Andromeda, deeply

Hubble snaps its deepest view of the cosmos yet, finding unexpectedly young stars in the halo of the Andromeda Galaxy. /// BY FRANCIS REDDY



HUBBLE'S TARGET AREA (above; white box) lies 36,000 light-years from the galaxy's nucleus and completely avoided the disk. T. M. BROWN (STScI) **THE ANDROMEDA DEEP FIELD** (right) is a four-image mosaic obtained with Hubble's Advanced Camera for Surveys. It reveals some 300,000 halo stars and up to 10,000 background galaxies. The four boxed regions appear in greater detail on the following pages. NASA, ESA, AND T. M. BROWN (STScI)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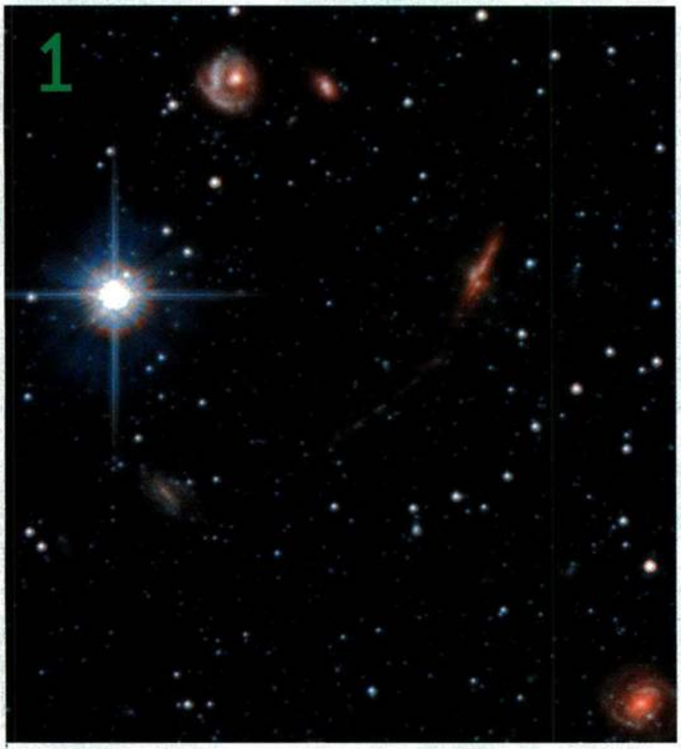
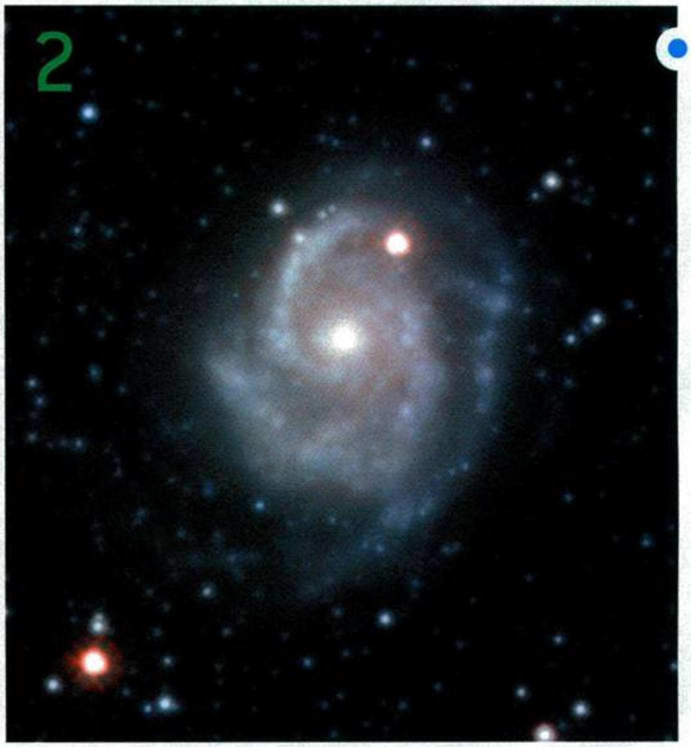


THE REDDISH ARC at first glance suggests a galaxy that has been gravitationally lensed by an unseen object. On closer inspection, it appears to be a chance superposition of two edge-on spiral galaxies.



THIS FACE-ON SPIRAL GALAXY appears to have at least one warped arm, most likely evidence that a galactic intruder long ago disrupted the host galaxy's graceful spiral form.

VISIBLE EVEN TO THE UNAIDED EYE AS A FOGGY SPINDLE OF LIGHT, THE Andromeda Galaxy (M31) is the most studied object outside our own galaxy. Just 2.6 million light-years away, it is the nearest large spiral galaxy, roughly similar in size, mass, and type to the Milky Way. A puzzling difference, however, is the surprisingly high abundance of elements heavier than helium among the stars of Andromeda's halo — a spherical region surrounding the galaxy's disk — relative to comparable Milky Way stars. A team led by Tom Brown of the Space Telescope Science Institute in Baltimore solved this puzzle by taking the deepest-ever look at M31.

Astronomers know the Milky Way's halo is deficient in those elements, referred to as "metals," a characteristic feature of stars that formed early in the galaxy's history. "We knew that the Milky Way halo was metal-poor and old," Brown says, "and we knew that the Andromeda halo was metal rich, but we didn't know how old it was." Telescopes could resolve only bright, giant stars in M31, stars that tell astronomers little about the history of star formation there.

That changed last year when astronauts installed the Advanced Camera for Surveys on the Hubble Space Telescope. The new instrument gives Hubble the largest field of view it has ever had — 202" by 202", or about twice the area of the Wide Field Planetary Camera 2 — and increases its sensitivity, allowing astronomers to reach objects at least a full magnitude fainter than those in the famous Hubble Deep Field image. "Now we can see the faint dwarfs, stars as faint as our own Sun and fainter" in Andromeda, Brown says.

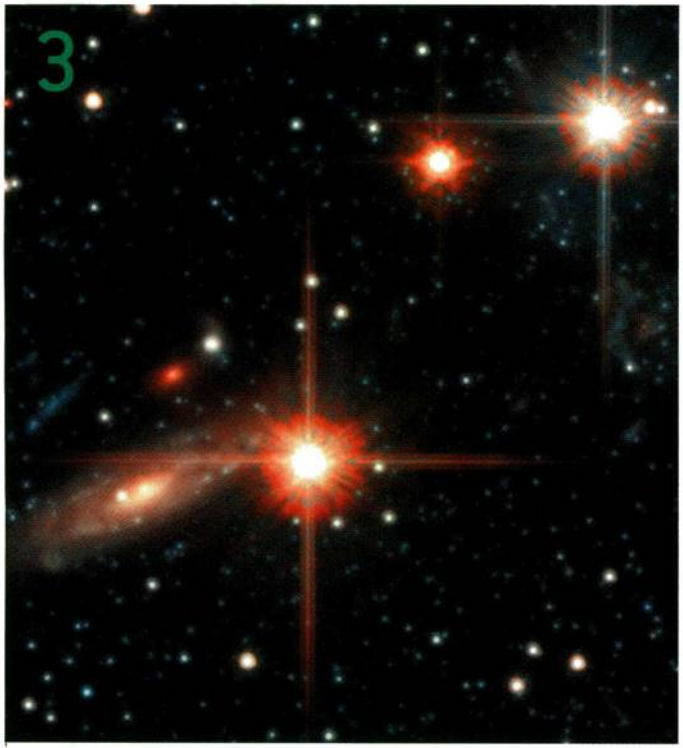
By analyzing the distribution of temperature and brightness in a stellar population, astronomers can tell just how old those stars are. Sorting the stars by temperature and brightness creates the Hertzsprung-Russell, or color-magnitude, diagram: blue stars on the left-hand side, red stars on the right, stacked bottom to top in order of increasing brightness. At some point in the history of a star group, most stars lie on a diagonal band that runs across the middle of the plot. That band, called the main sequence, represents stable stars that burn hydrogen in their cores like our Sun.

The brightest, bluest stars soon exhaust their core hydrogen and move toward the upper right of the plot, where red giants reside. Over time, progressively fainter stars of more moderate temperature and mass follow suit. The main sequence unzips as stars peel off and evolve into giants. The color-magnitude plot shows a kink in the main sequence where stable stars have begun to leave it. The color and brightness of the stars at the turnoff point reflect the amount of time elapsed since the group formed.

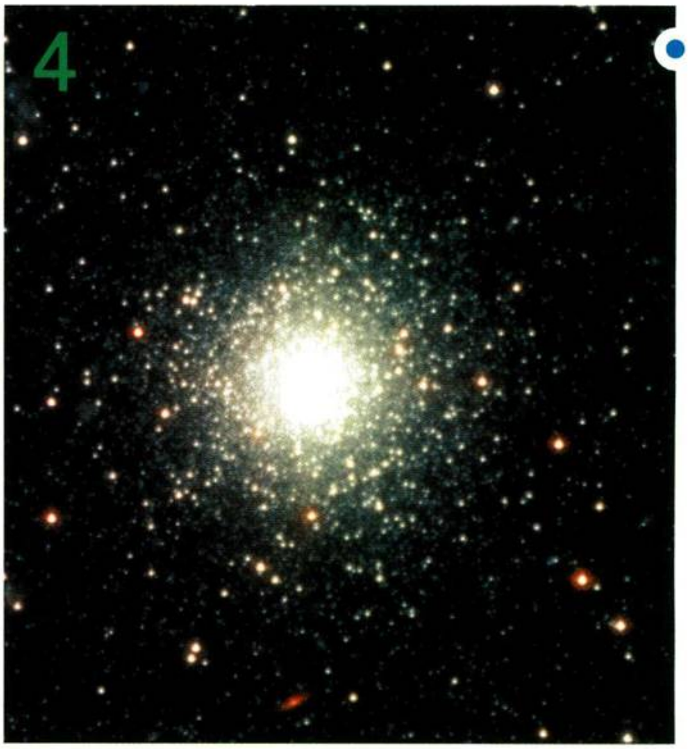
Brown's team wanted an image deep enough to examine halo stars below the main sequence turnoff. But deciding where to point Hubble required them to find a "sweet spot" between two competing factors. On the one hand, "We wanted it crowded enough to minimize contamination by both foreground stars in our own galaxy and background galaxies behind Andromeda, and we wanted to have good population statistics so we could really disentangle a complicated star formation history," Brown says.

On the other hand, the field had to be sparse enough so they could get accurate measures of the brightness of individual stars. The group also wanted the "cosmic core sample" to include one of Andromeda's hundreds of *globular clusters,* compact spheres containing as many as a million aged stars. The team also decided to calibrate the data by observing several well-studied Milky Way

Francis Reddy *is a freelance writer and museum exhibit consultant. His most recent book, written with Greg Walz-Chojnacki, is* Celestial Delights: The Best Astronomical Events through 2010 *(Celestial Arts, 2002).*



A RUDDY DISK GALAXY and a few bright stars in the Andromeda Galaxy's halo dominate this part of the deep field. More distant galaxies appear as irregular patches and nebulous clumps.



THE COMPACT GLOBULAR CLUSTER GC 312 contains some 100,000 stars and is one of several hundred similar "star balls" that orbit M31. Even in this crowded star field, several background galaxies emerge.

globular clusters — including 47 Tucanae and M92 — with the same filters used in the deep image.

The field they selected lies 36,000 light-years from M31's nucleus and contains the globular cluster GC 312. Between December 2, 2002, and January 11, 2003, Hubble peered into the zone for 121 orbits and made 250 separate exposures. The resulting image has a total exposure time of 3.5 days and penetrates to magnitude 31. An estimated 300,000 never-before-seen halo stars and thousands of new background galaxies pepper the frame.

With the star data in hand, says Brown, "we did the classical age diagnostics that have been applied to stars in our own galaxy for decades." While most of the stars fall into the same age range as stars in the Milky Way's halo — 11 to 13 billion years old — about 30 percent of Andromeda's halo stars turn out to be much younger, between 6 and 8 billion years old. Younger stars develop in an environment more chemically diverse than that in which halo stars formed, so such a significant population of younger stars explains the unusually high fraction of heavy elements in M31's halo. Brown presented the team's findings at the Space Telescope Science Institute's annual symposium in May.

Brown sees three possible explanations for the presence of the young stars. Perhaps repeated mergers of small galaxies pummeled M31's disk and blew newly formed stars out into the halo. Or perhaps a single, larger galaxy collided with Andromeda, and some of the interloper's young stars became mixed with the halo population. Alternatively, a galactic collision somehow may have fueled a new wave of halo star formation, producing the young stars right where we see them. Which of the scenarios works best, Brown says, is a problem for theorists. The findings support the view that giant galaxies like Andromeda and the Milky Way have grown by cannibalizing many smaller galaxies throughout their histories. And it appears that M31 has taken part in a major interaction much more recently than our own galaxy.

{ About 30 percent of Andromeda's halo stars turn out to be much younger than the vast majority of stars in the Milky Way's halo.

Between symposium talks, I pointed out to Tom Brown that he seemed almost embarrassed by all the attention given to the background galaxies. His rendition of the halo image emphasizes the stars, but the version released to the public — and which you see here — was enhanced to show off galaxies. "I was after the stars," he smiles, "and in any case, it's unclear how useful the galaxy images will be simply because all those stars are in the way."

He mentions that he was asked recently how an 8-meter space telescope would perform for this type of work. "It could do in an hour what took Hubble three-and-a-half days," he tells me. As we talk, he stretches his arms over his head, frames an imaginary field of view with his fingers, and mimes taking a snapshot. "With an instrument like that, you could pin down star formation history throughout the Local Group," he says. "If such a telescope ever materializes, that's exactly what I plan to propose." ◼

Send your questions via e-mail to: askastro@astronomy.com; or write to: Ask Astro, P.O. Box 1612, Waukesha, WI 53187. Please tell us your full name and where you live.

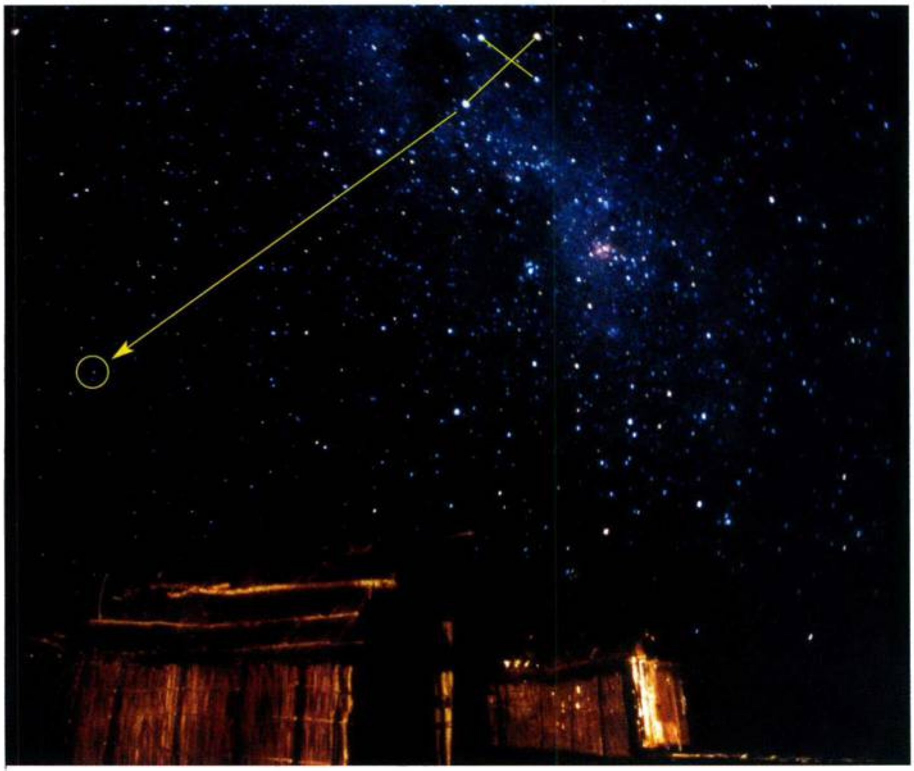
ASK ASTRO

Southern pole star, Cepheid variables, Moon's rotation

SOUTHERN POLE STAR

If the North Star is Polaris, then what's the south star?

— **JOHN MCBEE,** YANTIS, TEXAS



TO FIND THE SOUTHERN POLE STAR, Sigma Octantis (circle), start at Crux the Cross and extend the cross's long arm about 4.5 times its length. JERRY SCHAD

The answer is Sigma (σ) Octantis, a star that lies slightly more than 1° from the South Celestial Pole. But its similarity to Polaris stops there. Sigma is nowhere near as prominent as Polaris — at magnitude 5.5, it's barely visible to the naked eye under a dark sky, while Polaris shines conspicuously at 2nd magnitude. The Hipparcos satellite measured the distance to Sigma as 270 light-years; Polaris lies 431 light-years away, making it intrinsically about 60 times brighter than Sigma.

As it happens, Sigma's polar glory, such as it is, has passed its prime. The star's celestial position, like that of all stars, constantly shifts as Earth's axis precesses, wobbling like a toy top as it spins down. It takes about 26,000 years for Earth's axis to complete one precessional wobble. Sigma came closest to the South Celestial Pole in 1866, when it lay 43' away. About 7,000 years from now, precession will place the South Celestial Pole just 17' away from the 2nd-magnitude star Delta (δ) Velorum. No other naked-eye star comes as close.

Finding Polaris is easy for any northern observer who can locate the Big Dipper — just use the two outer stars in the bowl and extend a line five times the distance between them. Identifying Sigma Octantis is more difficult for southern observers. To find it, they locate the Southern Cross, Crux, and extend the length of its long arm four and a half times. — **ROBERT BURNHAM,** CONTRIBUTING EDITOR

CEPHEID VARIABLES

I've read a lot of explanations of how Cepheid variable stars can be used to calculate distances, but I have yet to see a cogent, step-by-step description. Can you help?

— **SHELDON FEUERSTEIN,** BOYNTON BEACH, FLORIDA

From a scientific standpoint, the key step came with the discovery that a Cepheid variable's average brightness and period of variability are related. In 1912, Harvard astronomer Henrietta Leavitt examined numerous photographs of the Small Magellanic Cloud (SMC), a satellite galaxy of the Milky Way. Although no one at the time knew this was a galaxy, astronomers recognized it as a single system.

Leavitt identified 25 Cepheids in the SMC and found that the brighter ones always took longer to go from maximum light to minimum light and back again. Because the stars all lie at similar distances, their relative apparent brightnesses track with their relative intrinsic brightnesses, or luminosities. Subsequent studies showed that this *period-luminosity relation* holds for all Cepheids in the SMC.

Of course, knowing the relative luminosities of these stars solves only half the problem. There's no way to determine a star's absolute luminosity without knowing its distance. Fortunately, a few Cepheids in the Milky Way lie close enough to Earth that their distances can be found by other methods, which calibrates the period-luminosity relation and allows astronomers to calculate distances to all other Cepheids. Because Cepheids are intrinsically bright, they can be seen up to tens of millions of light-years away, making them valuable yardsticks in our corner of the universe.

Returning to the question, astronomers determine a Cepheid's distance through observation and calculation. First, they observe the star over several cycles to get precise values for its period of variability and average brightness. Next, they use the period-luminosity relation to determine the star's actual luminosity. Then, they compare this luminosity to the observed brightness. Because an object's brightness drops as the square of the distance (a 100-watt light bulb 25 feet away looks four times brighter than one 50 feet away), the difference between apparent brightness and luminosity yields the star's distance.

As an example, suppose astronomers observe a Cepheid in the Large Magellanic Cloud, another Milky Way satellite, and find it has a period of 30 days and glows at an average magnitude of 13.3. The period-luminosity relation says a Cepheid with a 30-day period is 10,000 times more luminous than the Sun, the equivalent of 10 magnitudes. Scientists use 10 parsecs (32.6 light-years) as a standard distance to compare the absolute brightnesses of celestial objects. At that distance, the Sun would shine at magnitude 4.8, so our Cepheid would appear at magnitude 4.8–10 = –5.2. This difference of 18.5 magnitudes (–5.2–13.3) between actual and observed brightness is equivalent to a factor of 25 million. Because light falls off as the square of distance, the Cepheid must be 5,000 times farther away than 10 parsecs, at a distance of 50,000 parsecs or 163,000 light-years. — **RICHARD TALCOTT,** SENIOR EDITOR

MOON'S ROTATION

Why do we always see one side of the Moon and never the far side?

—TAMER ABDELKADER, SYDNEY, AUSTRALIA

Over the 4.6 billion years they have existed as a pair, Earth has raised tides of rock in the Moon. This tidal friction has changed the Moon's original rotation speed — whatever it might have been — so that the Moon now rotates on its axis in the same amount of time it takes to orbit Earth once. Planetary scientists call this *synchronous rotation*, and it's why we see only one side of the Moon.

THE MOON KEEPS ONE SIDE pointed toward us because it rotates once on its axis in the same amount of time it takes to revolve around Earth. BILL AND SALLY FLETCHER

To understand why synchronous rotation shows us only one face of the Moon, try a little experiment. Put a chair in the middle of a room and let it represent Earth. You, meanwhile, become the Moon. The room walls represent the distant stars, the reference for determining rotation.

Now walk a circle around the chair while facing it all the time. As you circle the chair, you are forced to keep turning in order to look squarely at it. By the time you reach the point where you started, you have made one full orbit of the chair (Earth) while also making one rotation relative to the walls (the stars). If someone had been sitting in the chair, all they would have seen of you is your front.

But this oversimplifies the actual situation. Three real-world complications, called *librations*, occasionally let us peek slightly onto the lunar far side. The first libration arises because the Moon's orbit is not circular, but elliptical. This means that its orbital speed around Earth varies during the lunar month, being fastest when the Moon is closest to Earth (perigee) and slowest when farthest away (apogee).

However, the lunar rotation rate stays constant. By the end of a given month, both rotation and orbit come out equal. But during the month, the Moon rotates a little faster than its orbital travel at apogee and a bit slower at perigee. At these times, we can look a bit beyond the Moon's western and eastern limbs, respectively.

A second libration occurs between moonrise and moonset. During the time the Moon is above the horizon, an observer travels one Earth diameter as our planet rotates. That's about 8,000 miles. This changes the observer's viewpoint by a small amount and again reveals a little bit of the far side.

The third libration results from the Moon's orbit inclining about 5° to Earth's orbit around the Sun. From time to time, this lets us look slightly over the north pole of the Moon and under the south one. Yet again, we have small regions on the far side presented to our view.

All told, these librations let us see up to 59 percent of the lunar surface from Earth. — **ROBERT BURNHAM,** CONTRIBUTING EDITOR

CELESTIAL PORTRAITS

THE GLORIOUS CONSTELLATIONS
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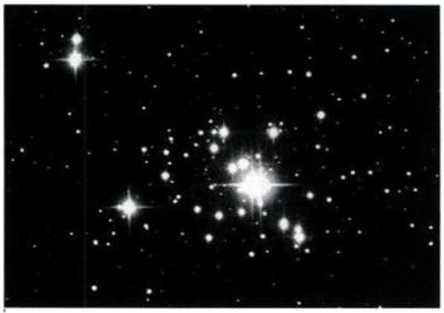
Camelopardalis & Ursa Minor

In the Giraffe and Little Bear, galaxies, nebulae, star clusters, and other stellar arrangements dance around the North Celestial Pole. /// BY TOM POLAKIS

This month we look at two constellations that are well placed year-round when viewed from mid-northern latitudes. One contains the Northern Hemisphere's "stationary" pole star. The other fills in the north polar sequence, a set of stars used to define magnitudes, between Cassiopeia and the Big Dipper. ☾ Camelopardalis the Giraffe is a sizeable constellation containing no stars brighter than 4th magnitude. The most prominent pattern of this star-poor area strings together five stars in a long arc near the Perseus border. The Milky Way slices through the southwestern corner of the constellation, resulting in fields rich with clusters and nebulae. Only three stars have Bayer (Greek letter) designations, although there are another dozen brighter than magnitude 5. Alpha (α) Camelopardalis is a distant giant shining with the light of tens of thousands of suns, while Gamma (γ) Camelopardalis resides 300 light-years away, virtually in our neighborhood.

The borders of Ursa Minor the Little Bear surrounds the North Celestial Pole. Begin by using the famous pointer stars in the bowl of the Big Dipper to locate Polaris. Currently 0.8° from the pole, this 2nd-magnitude star will make its closest approach to the pole at the end of the 21st century before slowly moving away. At the end of the Little Dipper's bowl are Beta (β) and Gamma Ursae Minoris, which are visible from any site. The faintest Dipper star is Eta (η) Ursae Minoris, which is 5th magnitude despite being less than 100 light-years away.

Only 2° from the galactic plane in southwestern Camelopardalis we find **Stock 23**, an attractive open cluster for small scopes. In a 9x60mm finder scope it appears as a clump, but at 50x it resolves into 20 stars scattered across a 15' diameter. Four of these stars are brighter than 8th magnitude, including the centrally located double star ADS 2426, whose two components are separated by 7". Look for a chain of four stars pointing at them from the west. The edge of Stock 23 is difficult to define among the rich surrounding star field.



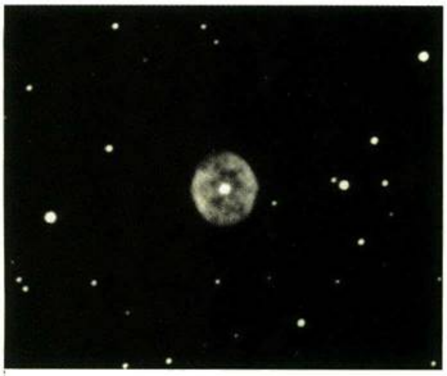
NGC 1502 is an open cluster that lies about 3,000 light-years away between the legs of Camelopardalis the Giraffe. PRESTON SCOTT JUSTIS

Our next object is a chance alignment of stars that was first described by the late Franciscan amateur astronomer Father Lucian Kemble, who found it while scanning the sky with binoculars. The asterism came to be known as **Kemble's Cascade**. A magnification of 15x is best for framing the chain of 15 stars, which extends 2.5°. Most of the stars, with the exception of the central 5th-magnitude gem are 7th to 9th magnitude. Even among these star-rich fields, the stellar chain is unmistakable.

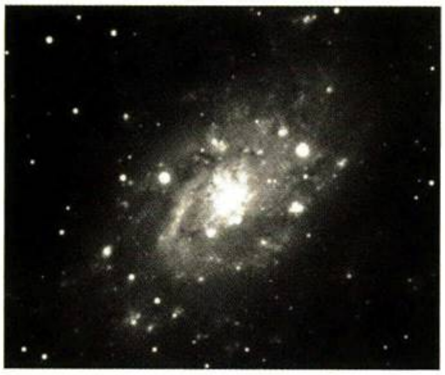
Near the southeast end of Kemble's Cascade and easily visible in the same view is the tight open cluster **NGC 1502**, located about 3,000 light-years away. Intervening dust dims the cluster's light by nearly two magnitudes. Even so, it's a pleasing sight. Through an 8-inch telescope, 25 stars between magnitudes 7 and 11 are grouped in an area 4' wide that's well set apart from the sparse surroundings. Most striking is a line of three equal-magnitude double stars. The easternmost of these is ADS 2984, whose components are each a spectroscopic binary. One pair is the eclipsing binary star SZ Camelopardalis.

Pan 1.5° due south to find the planetary nebula **NGC 1501**. A 10-inch scope shows a perfectly circular disk nearly 1' across. At high magnifications, the 14th-magnitude central star peeks through a slightly darker center that correctly suggests the presence of a thick ring structure. Some mottling appears on the surface of the nebula. These small bumps are part of a "boiling" shell that's of interest to professional

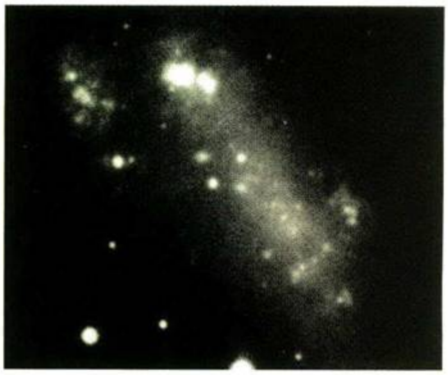
Tom Polakis *is an aerospace engineer who enjoys astrophotography and deep-sky observing. He lives in Tempe, Arizona.*



NGC 1501 is a circular planetary nebula 4,000 light-years away. Its 14th-magnitude central star sits within a dark inner region. KIM ZUSSMAN



NGC 2403 is the brightest northern galaxy not in Charles Messier's catalog. It belongs to the M81 galaxy group. CHUCK VAUGHN



NGC 2366 features a bright HII region at its southwestern end. The dwarf galaxy is another outlying member of the M81 group. KIM ZUSSMAN

astronomers. NGC 1501 is approximately 4,000 light-years away.

Three degrees south of Gamma Camelopardalis sits a spiral galaxy that would be as popular as the Whirlpool Galaxy were it not dimmed more than two magnitudes by the intervening Milky Way. **IC 342** is only 11 million light-years away and is as intrinsically bright as the Milky Way. Together with the galaxies Maffei I and II, it resides at the center of a galaxy group that's larger than the Local Group. Optically, IC 342 is about 20' across, but radio images indicate a diameter of 1.5°. Unfortunately, none of these superlatives translate to a good telescopic view. Look first for a bright central knot only 30" across in a rich star field. Surrounding this is a fainter halo 2' across, while an extremely faint, knotty structure extends over a diameter of 20'.

IC 356 is member 213 in Halton Arp's *Catalogue of Peculiar Galaxies*. Visually, it is a moderately faint, circular haze 2' across. A 10-inch scope shows mottled detail around a bright center. The galaxy is bracketed by stars of magnitudes 9 and 11 to the north and south.

From a dark site, an observer can spot a clump of four 6th-magnitude stars forming a triangle with Alpha and Gamma Camelopardalis. These stars belong to **Collinder 464**, which was catalogued as an open cluster but is actually a chance stellar gathering. It looks like a star cluster in binoculars, but a telescopic view at 30x or above shows no discernable edge or concentration of stars around the four brightest members of Collinder 464.

Lying in a rich star field is the variable star **S Camelopardalis.** Of the Mira type (characterized by a long period and large magnitude range), S Cam varies by four magnitudes over a period of just under a year. Even at its minimum luminosity, expect S Cam to stand out due to its orange hue, caused by sooty carbon at the star's surface.

Shifting to the eastern edge of Camelopardalis, we find the bright spiral galaxy **NGC 2403.** As part of the nearby M81 galaxy group, it is a mere 10 million light-years distant. This isolated object shows no signs of interaction with other galaxies. Its structure matches that of M33, the Pinwheel Galaxy. A fine spiral through modest telescopes, NGC 2403 appears at first as an oval haze 7' by 4' with a bright central region 2' across. Through a 13-inch scope, the spiral structure manifests itself as a slightly brighter halo at the periphery, but the origin of the arms is hard to trace. Using a magnification above 200x, look for bright stellar associations in the spiral arms, some of which have discernible size. A dozen stars shine in front of the galaxy.

Moving the scope 4° to the north brings the dwarf galaxy **NGC 2366** into view. Hardly a showpiece in its own right, it is home to an impressive HII region. Often incorrectly catalogued as NGC 2363, this emission nebula has the highest surface brightness in its class. It is ionized by two star clusters, the more energetic one of which is embedded invisibly in the cloud. An 8-inch telescope under a dark sky barely reveals the parent galaxy as a 4' by 2'

/// THE LITTLE BEAR

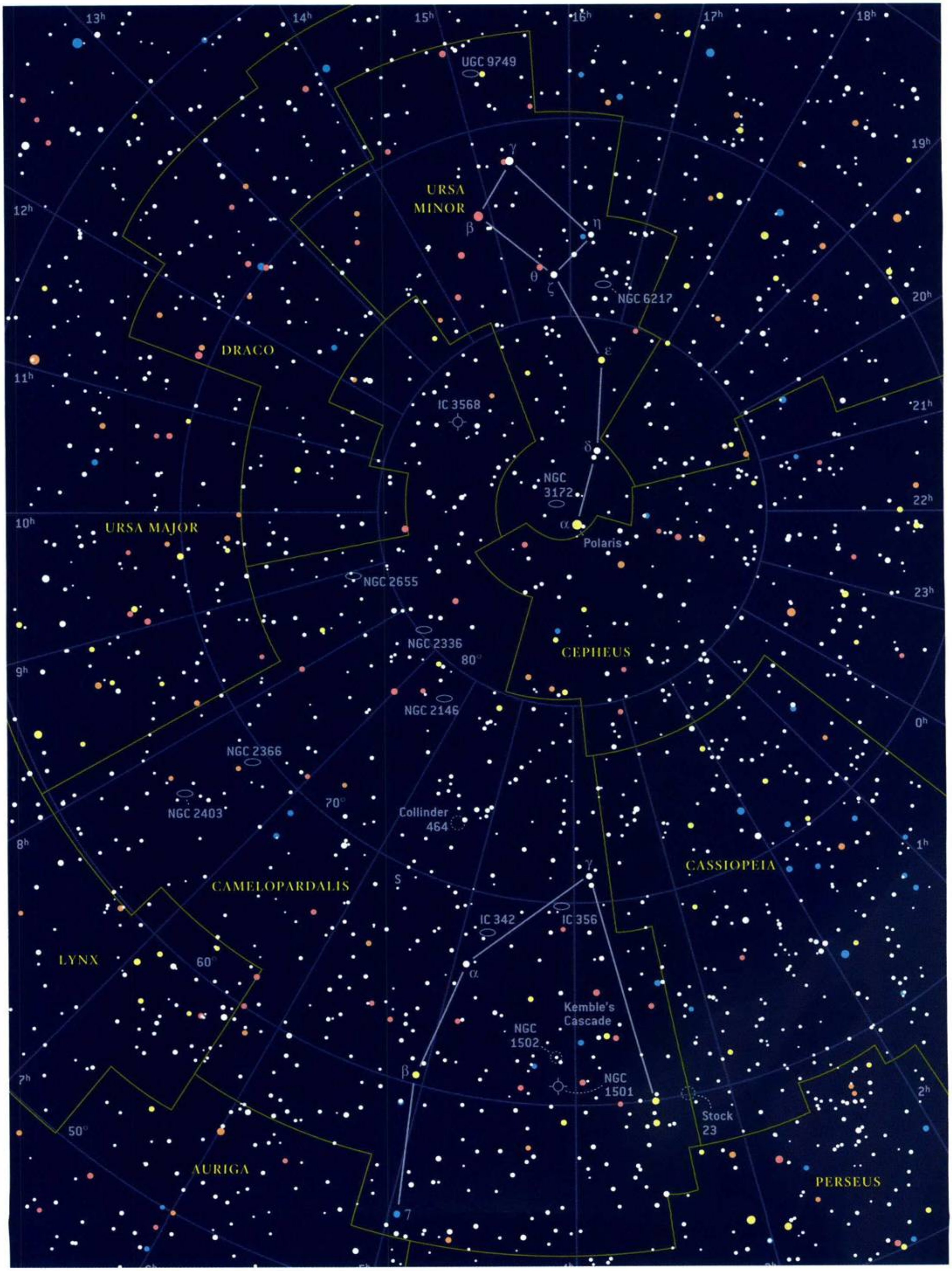
But Jove forbad, and snatch'd 'em thro' the air
In whirlwinds up to heav'n, and fix'd 'em there:
Where the new constellations nightly rise,
And add a lustre to the northern skies.
Metamorphoses, *Ovid (43 B.C. – 17 A.D.)*

Ursa Minor's greatest claim to fame lies at the end of the Little Bear's tail. Polaris, the pole star, is currently the closest bright star to the North Celestial Pole and appears not to move as Earth spins. Due to precession (the wandering of Earth's axis), Polaris holds this position for just several thousand years. About 5,000 years ago, Thuban in Draco was the pole star. And to ancient sky mappers, Ursa Minor was actually part of Draco, forming the dragon's wings.

According to some records, Draco's wings were first removed by the Greek philosopher Thales when he suggested sailors use the stars of Ursa Minor as a navigational aid. Other star-mappers may have distinguished Ursa Minor due to its resemblance to the Big Dipper in Ursa Major. In fact, one Greek tale links the two constellations together.

In the story, the Little Bear represents Arcas, son of the beautiful nymph Callisto and the god Zeus. Jealous of her husband's love for Callisto, Hera turned the maiden into a bear after Arcas was born. While hunting in the woods years later, a grown Arcas encountered his mother. Not recognizing her, Arcas was about to shoot the bear when Zeus intervened and turned him into a bear as well. Zeus then swung both bears into the sky by their tails, making their tails longer than those of their terrestrial cousins.

Hera was enraged by the celestial honor Zeus gave to Callisto and Arcas. She went to the god of the sea, Poseidon, who promised Hera that he would forbid the bears from swimming in his oceans. Indeed, from Greece and other northern countries, the two constellations are circumpolar, never touching the horizon. — *Vanessa Thomas*


13h
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3172
22h
10h
URSA MAJOR
α
Polaris
NGC 2655
23h
NGC 2336
9h
80°
CEPHEUS
NGC 2146
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NGC 2366
NGC 2403
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Collinder
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CASSIOPEIA
CAMELOPARDALIS
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IC 342
IC 356
LYNX
60°
α
Kemble's
Cascade
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PERSEUS
7

smudge but easily shows the HII brightening at the southwestern end. Viewed through an Oxygen III filter, the galaxy's light is diminished to invisibility while the HII region remains bright. The nebula is about 5" across and has a bright center. The real NGC 2363 is a faint and tiny companion galaxy 1' west of the bright HII region and becomes visible in only the largest telescopes.

Heading northward, we come to a spiral galaxy undergoing a major burst of star formation. **NGC 2146** is a moderately bright object through a telescope. It appears 3' long and half as wide, displaying a very broad central concentration and a faint, embedded nucleus. Telescopes with apertures larger than 10 inches show some mottling close to the core and a dark, subtle lane near the southwestern edge. In deep images, this lane resembles a skeletal hand, leading to NGC 2146's nickname, the Dusty Hand Galaxy.

The spiral galaxy **NGC 2336** has a prominent bar and lies more than 100 million light-years away. Visually, it exhibits a bright nucleus surrounded by a glowing, 4' by 2' halo. The galaxy IC 467 shows up almost as well 20' to the south-southeast.

NGC 2146 lies about 40 million light-years away. It is often called the Dusty Hand Galaxy for the skeletal look of its dark lanes. KIM ZUSSMAN

A second spiral nearly as distant as NGC 2336, **NGC 2655** is another member of Arp's collection. Arp 225's peculiarity comes from its amorphous central region. This bright galaxy is circular and has a much brighter nucleus surrounded by a faint outer halo. Velocity studies of NGC 2655 show that the innermost 3,000 light-years of its diameter rotates like a rigid disk.

/// Deep-sky objects in Camelopardalis and Ursa Minor

OBJECT	R. A.	DEC.	MAG.	SIZE	TYPE	NOTES
Stock 23	3h16.3m	60°02'	—	14'	OC	—
Kemble's Cascade	4h00.0m	63°00'	—	2.5° long	AST	Star chain
NGC 1501	4h07.0m	60°55'	11.5	52"	PN	—
NGC 1502	4h07.7m	62°20'	5.7	7'	OC	—
IC 356	4h7.8m	69°49'	10.5	4.6' by 4.1'	Gal	SA(s)ab
IC 342	4h46.8m	68°06'	8.4	21.4' by 20.9'	Gal	SAB(rs)cd
Collinder 464	5h22.0m	73°00'	4.2	120'	OC	—
S Camelopardalis	5h41.0m	68°48'	7.7–11.6	327 days	Var	Semi-regular variable
NGC 2146	6h18.7m	78°21'	10.6	5.4' by 4.5'	Gal	SB(s)ab
NGC 2336	7h27.1m	80°11'	10.4	6.4' by 3.3'	Gal	SAB(r)bc
NGC 2366	7h28.9m	69°13'	10.8	8.2' by 3.3'	Gal	IB(s)m
NGC 2403	7h36.9m	65°36'	8.5	25.5' by 13.0'	Gal	SAB(s)cd
NGC 2655	8h55.6m	78°13'	10.1	6.0' by 5.3'	Gal	SAB(s)0
NGC 3172	11h47.2m	89°06'	13.8	1.1' by 0.8'	Gal	Polarissima
IC 3568	12h32.9m	82°33'	10.6	10"	PN	—
UGC 9749	15h08.8m	67°12'	10.9	41' by 26'	Gal	Ursa Minor Dwarf
NGC 6217	16h32.6m	78°12'	11.2	3.3' by 3.3'	Gal	(R)SB(rs)bc

Object: Designation in NGC or other catalog. **R. A. and Dec.:** Right ascension and declination in epoch 2000.0 coordinates. **Mag.:** Visual magnitude. **Size:** Size in arcminutes or arcseconds. **Notes:** Hubble types for galaxies.

NGC 2336 is a barred spiral seen nearly face-on. The remote galaxy lies more than 100 million light-years from Earth. CHUCK VAUGHN

Only 8° from the celestial pole, the planetary nebula **IC 3568** appears as a very bright but tiny disk. The inner 5" core appears almost "overexposed," and its bright surface does not easily yield the 13th-magnitude central star. This feature is surrounded by a slightly fainter 15" shell. A 12th-magnitude star lies just 15" to the west. IC 3568 is one of the most perfectly circular planetary nebulae, leading astronomer Bruce Balick to write that if it did not exist, it may have been created by theoreticians.

We move next to a galaxy that has the distinction of being the NGC object closest to the North Celestial Pole. **NGC 3172** in Ursa Minor is also known as Polarissima. An 8-inch telescope at a dark site barely picks it up as an extremely faint haze less than 1' across with a slightly brighter core.

Also in Ursa Minor, **NGC 6217** is a nearly face-on, ringed spiral galaxy 80 million light-years away. Make a triangle with Zeta (ζ) and Eta Ursae Minoris to find it. Its faint oval form looks 2' long and contains a small, intense core inside a bright central region. In a "light bucket," a bar and spiral arms appear as well as a faint, superposed star immediately southeast of the core.

We finish with the extremely faint Local Group member called **UGC 9749** or the Ursa Minor Dwarf. Only 220,000 light-years away, or one-tenth the distance to the Andromeda Galaxy, the tiny system has a catalogued diameter of a half degree. Only the central 5' area shows up in a 13-inch scope, and it becomes recognizable as a brightness change across the field of view when the telescope is moved slightly. A close look through a 20-inch scope will yield the galaxy's brightest member stars, which are 16th magnitude. The Ursa Minor Dwarf is similar in size and brightness to the Draco Dwarf 20° to the east. ■

TRAVEL

Star parties in California's Yosemite National Park offer amateur astronomers clear, dark skies and the chance to observe from one of the most beautiful spots on Earth. /// BY ROBERT NAEYE

Astronomy in paradise

Consider Dave Balogh, the "Mr. Versatility" of National Park rangers. Like most of his ranger colleagues at Yosemite National Park, Dave spends his days interpreting natural history for the public. But Dave is equally at home in the dark. An experienced amateur astronomer, he has either conducted or organized public stargazing sessions from Yosemite's Glacier Point for 30 years.

Dave presented his first public stargazing program in 1973. Over the years, the programs became increasingly popular. By 1983, Dave faced a serious challenge. "The programs were such a success, and the lines were so long that once I counted 400 people who wanted to look through one telescope," he recalls. "I knew we needed to either increase the number of telescopes or restrict the number of park visitors who attended the programs. We chose the former solution." And thus was born the Yosemite Star Party.

Two decades later, unsuspecting weekend visitors to Glacier Point see a strange sight as the Sun sinks low in the western sky: a group of people setting up telescopes in an outdoor amphitheater (built in 1997) overlooking Half Dome, Vernal Fall, and Nevada Fall. The high-tech equipment looks out of place in the rustic location, often leading to expressions of bewilderment from tourists and hikers.

Astronomy clubs lend a hand

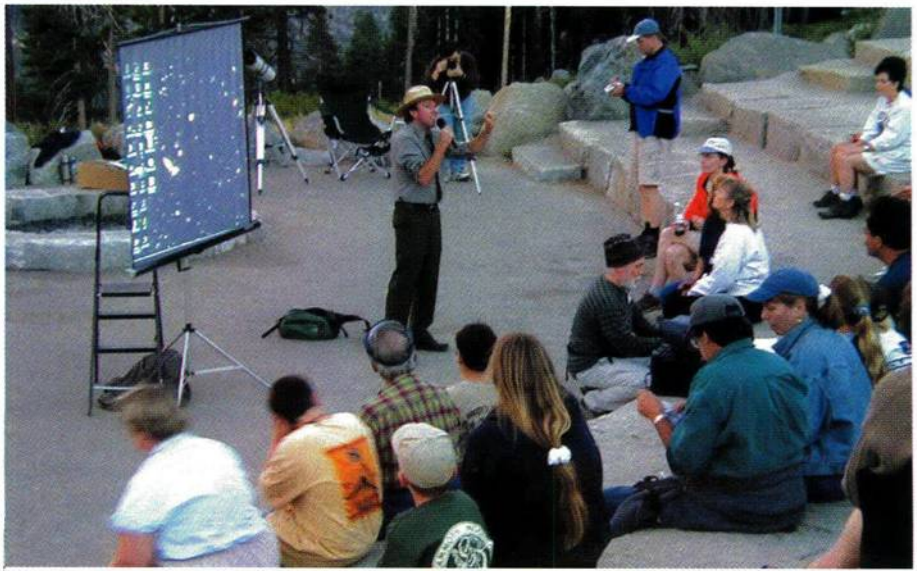
On different weekends during the summer, amateur astronomers from clubs in Central and Northern California set up telescopes in Yosemite. They share their love of astronomy with thousands of park visitors annually and take advantage of the dark skies and good seeing afforded by Glacier Point's remote location at an altitude of 7,214 feet. Plus, they get to enjoy one of the most scenic spots on Earth. The daytime view from Glacier Point is so spectacular that a young couple visiting from Milan told me, "This is as beautiful as anything we have in the Italian Alps."

The idea of having amateur astronomy clubs come to Yosemite was the brainchild of Dave Balogh. To him, inviting the clubs was the perfect solution to his problem of having too many people and too few telescopes. "I suggested to the park administration that we start inviting members of astronomy clubs to provide public star parties in exchange for a weekend of free entrance and a place to camp in the park. The National Park Service was very supportive of the idea, and I was given the job of coordinating it," says Balogh. "We contacted clubs in the Northern California area and now have ten that participate."

Balogh randomly assigns each club a weekend from mid-June through Labor Day. Club members enjoy a great observing site and also receive free admission to the park, a group campsite for up to 30 people at nearby Bridalveil Campground, and permission to observe all night long from Glacier Point. It's hard to imagine a better place on Earth for a star party.

Club duties

Clubs are encouraged to provide at least one telescope for solar observing and 15 telescopes for nighttime observing. Almost all the clubs present a slide show as darkness descends upon Glacier Point. Club members are expected to follow certain rules; with privileges come responsibility. They must be tolerant of park visitors not



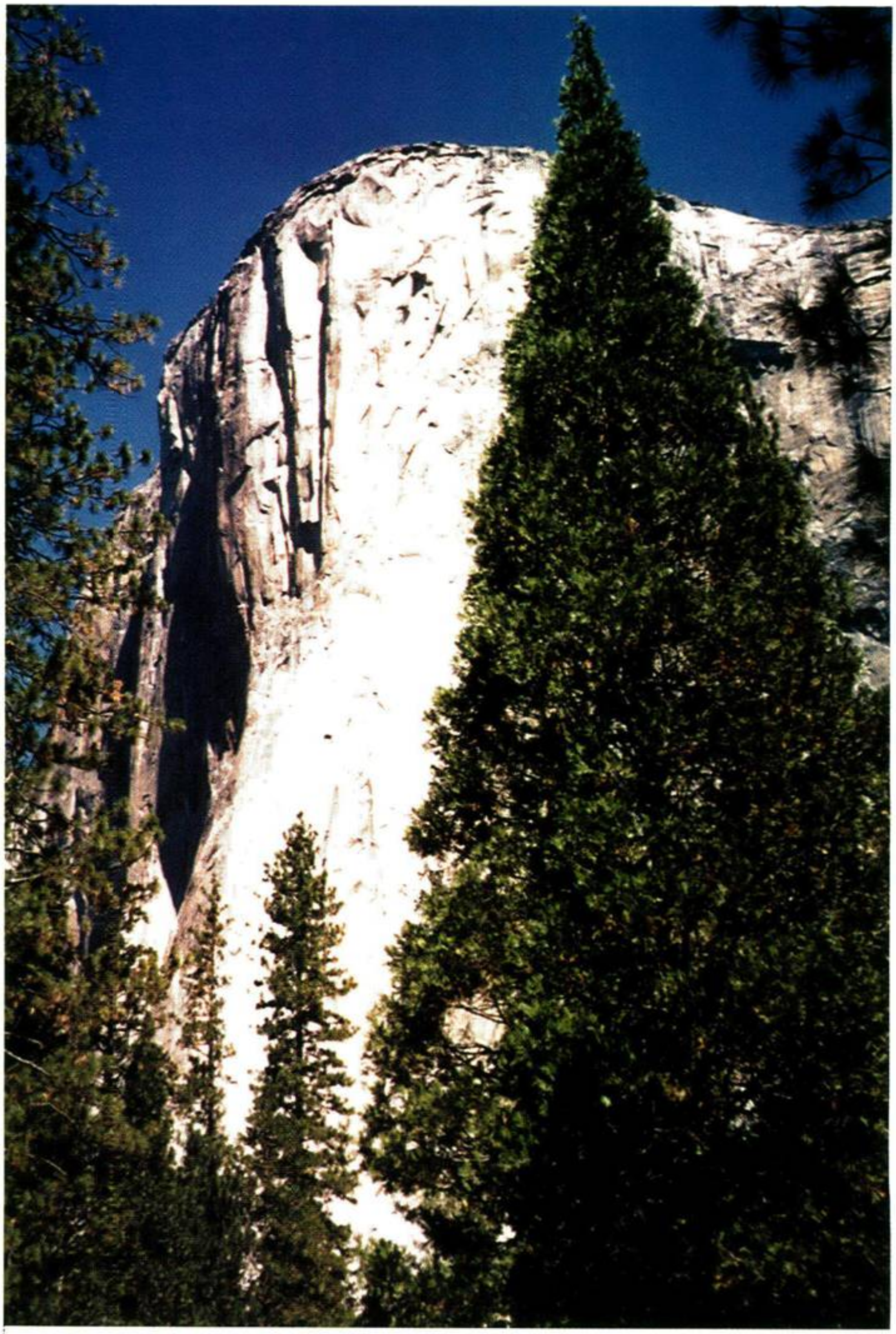
INTERPRETIVE RANGER DOUG NOWLIN begins his introductory remarks to the evening's star talk as visitors gather at Yosemite National Park's Glacier Point. RICK BALDRIDGE

DAVE BALOGH, the founder and organizer of the Yosemite Star Party, often makes introductory remarks to visitors and introduces the evening's speaker. RICK BALDRIDGE

accustomed to the rules of amateur astronomy, such as the prohibition of using flashlights in the dark.

Besides solar observing, club members often point out Venus in the daytime. For fun, they also aim their telescopes at rock climbers who brave the strenuous trek up the mountain's sheer vertical granite face to reach the summit of Half Dome two miles from Glacier Point.

But it's the early evening when most of the astronomers appear. They begin setting up telescopes an hour before sunset. These telescopes range from small refractors to 20-inch Dobsonians. During setup, amateurs see the Sierras turn a beautiful pink, then purple, as darkness descends. At this time, the public starts gathering in the amphitheater. As the last bit of twilight fades, usually about 150 people are waiting for the slide show. The shows offer clubs an opportunity to explain their purpose to the assembled throng. Speakers also note the objects visitors can expect to see through the telescopes.



EL CAPITAN is one of the most recognizable wonders of the natural world. If you're headed to the Yosemite Star Party, don't miss it. ROBERT NAEYE

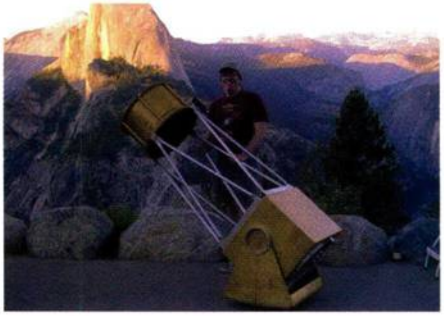
Sharing the sky

All scheduled star parties are advertised in the *Yosemite Guide*, a free newspaper distributed at park entrance stations and online at www.nps.gov/yose/trip/stargazing.htm. But most visitors have no idea that a public astronomy session will be taking place in the evening. Still, sometimes word gets out. "Last summer, a group of Asian-Americans from San Francisco heard that the San Francisco Amateur Astronomers, the SFAA, were going to be leading a Yosemite Star Party," recounts amateur astronomer Al Stern, former president of SFAA. "They brought 200 people and filled the amphitheater."

The instant the slide show ends, chaos ensues as the public quickly descends upon the telescopes. With the crowd's expectations high, the astronomers better be ready to point their telescopes at something interesting. I've discovered the key to success is to aim at the showstoppers. Using my 12.5-inch reflector and my 102mm refractor, I seem to get the loudest "oohs" and "ahs" from two objects in particular: the blue-and-gold double star Albireo (β Cygni) and the ghostly, tendriled crescents of the Veil Nebula (NGC 6960 and NGC 6992–5). I also get strong reactions when visitors see the Lagoon Nebula (M8), the Hercules Cluster (M13), the Ring Nebula (M57), the Dumbbell Nebula (M27), the Andromeda Galaxy (M31), and the Whirlpool Galaxy (M51).

I often give people a basic sky tour. I point out the major constellations and bright stars and show people where in the sky the telescope is pointed. I also like to explain how the telescope works, saying

EVEN BEFORE NIGHTFALL, telescopes provide views of the beautiful surroundings, such as a distant peak. JANE HOUSTON JONES



MIKE KOOP and his 17-inch Dobsonian-mounted reflector seem nearly as large as the magnificent Half Dome formation in the background. BOB HAVNER

TELESCOPES OF ALL SIZES and styles, some with computer or video setups, are always on hand to allow visitors excellent views of celestial objects. JANE HOUSTON JONES

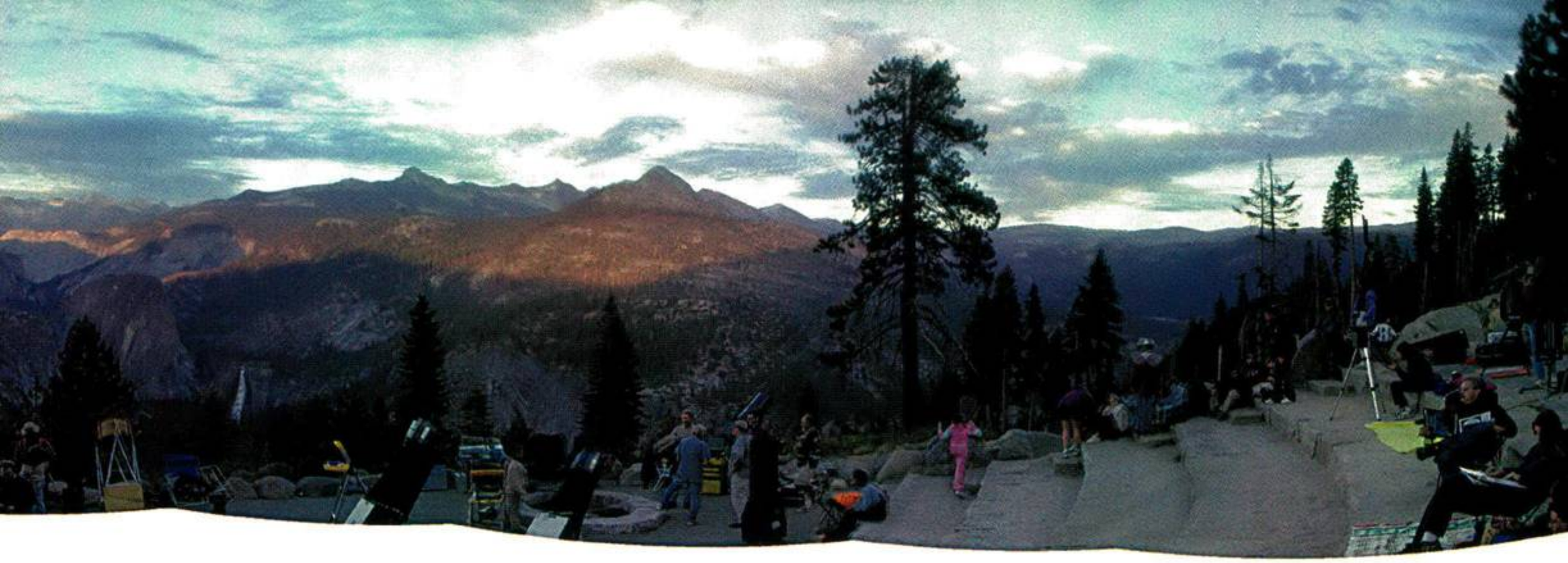
my reflector uses the same basic optical design invented by Isaac Newton in the 1600s. One of the many wonderful experiences at Yosemite star parties is that you meet visitors from all over the world, and it's not uncommon to hear 5 or 10 different languages spoken on a single night.

After midnight

Once the public session winds down, usually about two hours after sunset, people return to their lodges or campsites. That's the time we astronomers have the mountain more or less to ourselves, and we're free to chase down 14th-magnitude galaxies without feeling pangs of guilt. After midnight, amateur astronomers rule the roost. We even have permission to tell the occasional straggler to turn off his or her flashlight. Without the crowds around, the distant rumbles of Vernal Fall and Nevada Fall are audible despite being more than two miles away.

Midnight is also the time when the astrophotographers fire up their CCD cameras. When that happens, green lasers are strictly off limits. During the Peninsula Astronomical Society weekend last summer, I momentarily forgot standard etiquette and pointed my green laser at the great globular cluster in Hercules, M13. I was instantly admonished by my friend Paul Mortfield who, besides being an advanced astrophotographer, is an avid hockey player originally from Canada. When Paul tells you to turn off your green laser, you turn it off.

Robert Naeye *is editor of* Mercury, *the bimonthly magazine of the Astronomical Society of the Pacific. He is a member of five San Francisco Bay Area amateur astronomy clubs and a frequent attendee of Yosemite Star Parties.*



THIS GLACIER POINT PANORAMA provides a small glimpse at the magnificent beauty that surrounds visitors to the Yosemite Star Party.

JANE HOUSTON JONES

Around 1 A.M. in late summers, we watch the breathtaking sight of the Pleiades (M45) rising directly over Half Dome. And depending on the date, we're also on the lookout when a Last Quarter Moon rises over the Sierras.

One of my most memorable skygazing experiences occurred on a Sunday night late last August at Glacier Point, not during an official Yosemite star party. My friend Bob Berman (author of *Astronomy*'s Strange Universe column) and his daughter Anjali were visiting California.

Knowing Bob's love of astronomy and natural beauty, I took them to Yosemite. Bob figured out exactly when and where the Moon would rise. We aimed my refractor at that spot and gaped in awe at distant pines and firs — at least a dozen miles away — silhouetted against the rising Moon. Several other people were there, so we each enjoyed only brief glimpses. This is one of the few times in my life when I really wanted to hog the telescope.

A few days later, I visited again, this time for an official star party weekend with the Santa Cruz Astronomy Club. One of its members, Craig Wandke, is a lunar fanatic, which is just partially evidenced by the word "craterman" in his e-mail address. To this day, Craig can't understand why so many amateur astronomers forsake the Moon and observe faint galaxies that barely rise above the threshold of visibility. When the Moon rose around 1 A.M. on Saturday, the rest of us packed up our belongings and headed back to the campground. But for Craig, the time for exciting observing was just starting. When I saw him the next day, he had produced a series of stunning drawings that showed exquisite detail of lunar craters and mountains. I often think Craig knows something the rest of us deep-sky buffs don't.

That's the great thing about Yosemite — it offers something for everyone. In the daytime, visitors can gaze at towering waterfalls, hike one of hundreds of trails, watch rock climbers on El Capitan, or wade in the Merced River. At night, the stars beckon in droves. As Dave Balogh explains, "The stars are as much a part of Yosemite as the granite, sequoias, or mammals that reside there. Besides, how many things can you think of that you can do in the woods at night?"

/// IF YOU WANT TO GO . . .

The astronomy clubs of Central and Northern California cordially welcome you to attend their Yosemite star parties. Except for certain Full Moon weekends, you can expect to find telescopes set up at Glacier Point Friday and Saturday nights between June 21 and Labor Day. Often, club members will come a day early and stay a day late to set up telescopes on Thursday and Sunday nights, especially on holiday weekends like July 4 and Labor Day.

If you're not a member of one of the ten clubs that have official Yosemite star parties, and you want to bring your own telescope, you must first obtain permission from the club assigned to that particular weekend. Some clubs, such as the Peninsula Astronomical Society, bring 30 to 40 amateurs with telescopes, filling the small amphitheater to capacity. Naturally, anyone may bring his or her own telescope to Glacier Point Sunday through Thursday nights. But free camping and entrance to the park aren't provided. If you set up your telescope around sunset, be prepared for lines that may last several hours.

Wear light clothes in the daytime — summer temperatures climb into the 80s — and bring sunscreen. If you venture into Yosemite Valley, temperatures often exceed 90° F. Bring plenty of layers for nighttime, when temperatures often drop into the low 40s or upper 30s at high-altitude campgrounds like Bridalveil.

For directions to Yosemite, along with information about the park itself, lodging, food, trails, wildlife, and geology, visit the official Yosemite National Park website at www.nps.gov/yose.

ROBERT NAEYE

ASTROPHOTOGRAPHY

If you're thinking about CCD imaging, this complete step-by-step guide will help you get started. /// PHOTOS AND TEXT BY JACK B. NEWTON

Basic CCD techniques

THE ORION NEBULA is the best known area of star formation in the sky. The author captured this image, along with the Running Man Nebula (bottom), using his Meade 7-inch f/9 APO refractor. The exposures were Hα = 6 minutes, R = 3 minutes, G and B = 4 minutes each, taken with a Finger Lakes Instrumentation Dream Machine CCD camera.

When the first ad for the Santa Barbara Instrument Group (SBIG) ST4 CCD autoguider appeared back in 1990, I was among the first to purchase one. What an incredible idea — no more manual guiding, no more freezing while standing atop a 10-foot ladder at 2 A.M., and the end of painstakingly keeping a guide star riveted to the crosshairs of an illuminated eyepiece at 600 power. I would be able to simply "fire-up" the autoguider, select a guide star, and go!

When the ST4 arrived, I didn't own a personal computer. I called my friend Bob McBay to bring his PC over to help me put the ST4 through its paces. We quickly centered the Ring Nebula (M57) and took a 10-second exposure. Our mouths gaped as the Ring — complete with central star — appeared in all its glory on the monitor.

That camera was truly an amazing instrument. I repeatedly used the ST4 for imaging and liked it so much that I never got around to using it as an autoguider.

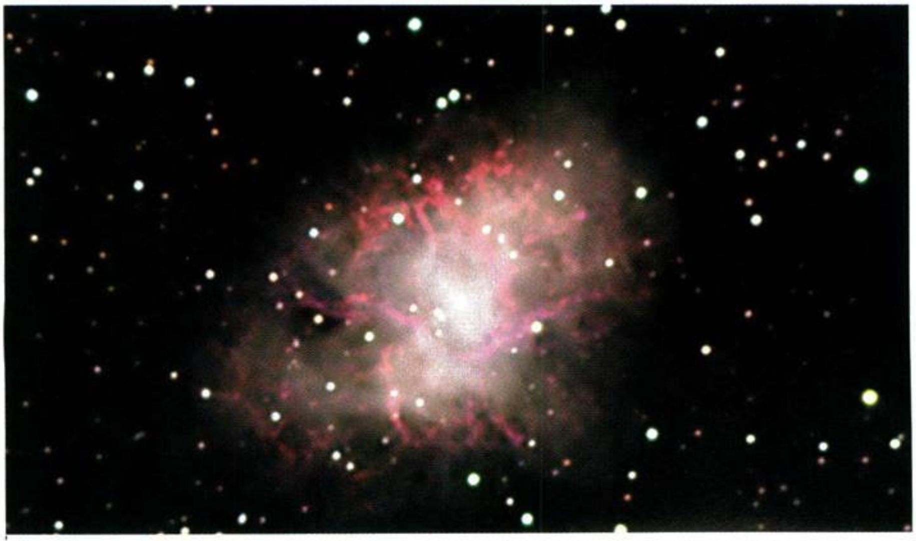
The color process

CCD color imaging involves three separate exposures of the same object, one each through red (R), green (G), and blue (B) filters. An infrared "blocking" filter, which stops infrared light from leaking through, is also used for each exposure. The three images are combined later to form "true-color" renditions of objects in the night sky. Let's look at the word *true*. If the CCD camera is perfectly color balanced (that is, if an exposure through the red filter captures the same amount of light as exposures taken through the green and blue filters), then an "RGB" composite of equal exposures should produce a truly "balanced" (in color) image of an object. In reality, a CCD camera's red sensitivity is usually twice that of its blue sensitivity.

To compensate for this disparity, you will need to identify the correct color ratio for your camera. For an SBIG ST6 CCD camera I later purchased, I used a ratio of one part red to five parts green to 16 parts blue (sometimes written as R:G:B = 1:5:16). I reached this formula using a Kodak gray card, which reflects equal amounts of the visible spectrum when illuminated with sunlight. I started with the most sensitive color (red) and exposed the card to about half of my computer's 65,000 shades of gray. Then I increased the green, followed by the blue, to equal the density of red, until I produced a color image of the gray card visually comparable to the original.

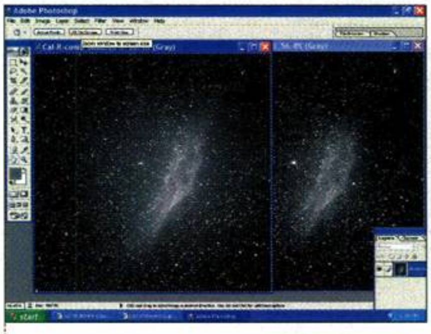
Another way to color balance a CCD camera and filter set is to select a white star and defocus it so it appears as a soft "doughnut" approximately an inch across on your monitor. Vary the exposure times of R, G, and B until the star has equal amounts of each color. The resulting image will be white.

The ST6 brings back fond memories. My wife Alice and I visited SBIG on our return from the 1991 solar eclipse in Baja, Mexico. We were shown the "alpha" model of the ST6, which soon thereafter became the first commercially available 16-bit CCD camera. Although the company was

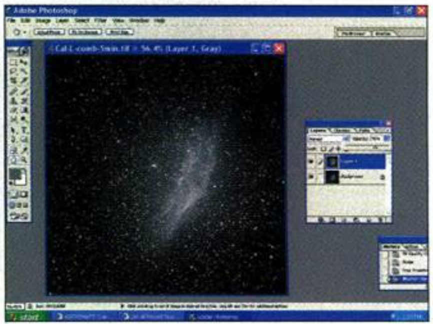


THE CRAB NEBULA (M1), a supernova remnant in Taurus, was imaged with a Meade 16-inch f/10 LX200 scope and a Finger Lakes Instrumentation Dream Machine CCD camera. The exposures were Hα = 10 minutes, R = 8 minutes, G and B = 10 minutes each.

/// PHOTOSHOP PROCESSING



AN EARLY STEP in the author's Photoshop processing technique shows the California Nebula's luminance and Hα images ready to be combined.



THE PHOTOSHOP PROCESSING continues. This screen shot shows the luminance and Hα images combined and flattened, ready to be merged with the RGB color image.

Adobe Photoshop is a good program to use for adjusting the mix between two images. Since the luminance image contains most of the resolution, additional processing (with sharpening or deconvolution) can greatly improve the final picture when the luminance channel is knitted into the color image.

In Photoshop, open both the luminosity (L) and Hα image files. Click on the Hα image. On the task bar at the top of the screen, click on *select* and *all*. A dotted line will surround the image. Click on *edit* and *copy* in the pull-down menu. Click on the L image and select *edit* from the top task bar. Select *paste* from the drop-down menu. Choose window on the top task bar and open *layers* from the drop-down menu.

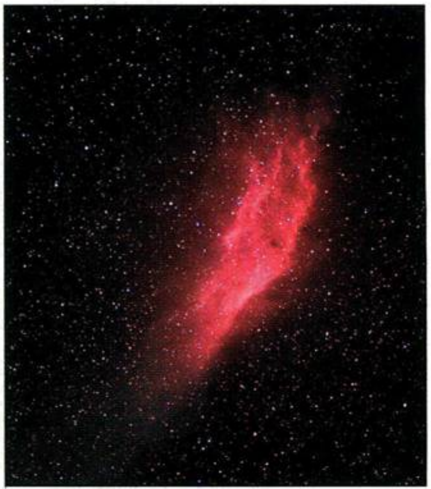
In the layers box, click on the opacity triangle on the right side. A drop-down slider will adjust the mix between the L and Hα images. I have found that an opacity of 70 percent works best. Select *layer* from the top task bar and click on *flatten image*. The L and Hα images are now combined into one image. Use *save as...* in the *file* menu to save the new image (let's use the name "LHa.tif" for our example).

Open the RGB image. Click on the triangle in the upper right corner of the layers window. Select *new layer* in the mode box. Select *luminosity* from the drop-down menu. Open LHa.tif. Click on *select* and choose *all*. Select *edit* and then *copy*. Highlight the RGB image, select *edit*, and click *paste* from the drop-down menu. Select *layers*. Adjust opacity to taste. (I used 80 percent for the accompanying screen shot.)

Because the addition of luminosity will dilute the color saturation, select *image* from the task bar. Click first on *adjustments* and then *hue/saturation*. Use the slider to choose a level from +13 percent to +15 percent. Now return to image. Select *adjustments* and then *curves*. Use the computer's mouse to move the drop-down box's diagonal line by clicking on the line and dragging it. Clicking on the line will freeze points from moving in that portion of the image. This is a very powerful tool, and some practice (and the built-in tutorials) will help you master this adjustment.

Photoshop has myriad other options to improve images. Be sure to save all major variations of the image so that you can return to previous images at a later date as your processing skills improve. By all means experiment, but archive your raw data.

The foregoing represents only a few of my general processing tips. Each astronomy imager has favorite methods for acquiring and processing gorgeous deep-sky images. Manufacturers introduce new CCD equipment all the time, so the sky truly is the limit!



THE CALIFORNIA NEBULA in Perseus was imaged by the author with a 300mm telephoto f/2.8 lens attached to a Finger Lakes Instrumentation Dream Machine CCD. The exposures were Hα = 10 minutes, R = 8 minutes, G and B = 10 minutes each.

reluctant to ship a unit with circuit boards hanging out the back, CEO Richard Schwartz was excited to see what test images might emerge. I was allowed, therefore, to beta-test the ST6. And what a test it was! Three different voltages had to be alligator-clipped to the camera, and the equipment was balanced on top of a 6-foot stepladder to reach the focus 10 feet off the floor. I realized then that CCD imaging was coming of age, and that Alice soon would be able to reclaim freezer space by tossing out all the canisters of film stored there.

Balance and align

A good starting point for CCD imaging is an 8-inch or 10-inch alt-azimuth-mounted Schmidt-Cassegrain telescope with go-to capability. Adding a CCD camera requires adding counterweights. One weight is attached to the front of the telescope tube and one to the side (running the full length of the tube). Balance the scope by sliding the side weight forward or backward. The telescope must balance in both directions, i.e., vertically as well as horizontally. Cables from the camera should be attached to the mount's fork so they do not affect the balance.

A telescope's alt-azimuth configuration can be improved for CCD imaging by using a device called a "field de-rotator," which keeps the star field from rotating relative to the CCD camera. The best method for astrophotography, however, is to use an equatorial wedge and align the telescope to the North Celestial Pole. In this configuration, the azimuth motor becomes a right ascension motor as it compensates for the westward drift of the stars. Many imagers also use a secondary guide scope with an autoguider CCD camera (just like my old ST4).

Jack B. Newton *is a world-renowned astrophotographer and manager of Arizona Sky Village in Portal, Arizona.*

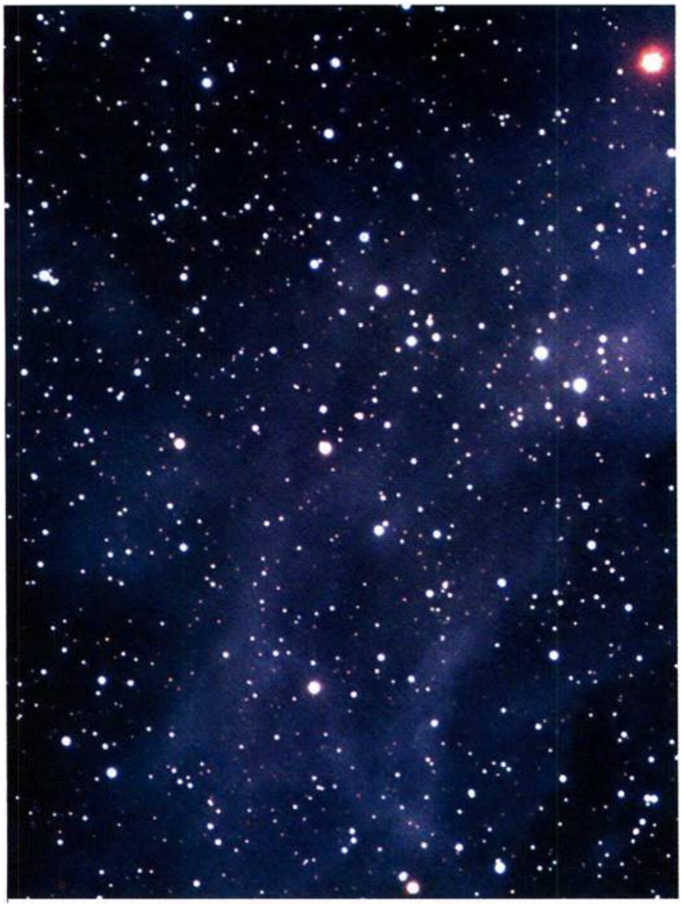
COMET C/2002 V1 NEAT was imaged with a Meade 7-inch f/9 APO refractor and Finger Lakes Instrumentation Dream Machine CCD. This was a 2-minute exposure.

Another step is necessary. Before you attach the CCD camera, place a terrestrial object (or, if at night, a bright star) in the field of view of a medium- to high-power eyepiece and carefully adjust the finder scope's adjustment screws. You will not be able to see through the telescope when the camera is attached, so a properly aligned finder ensures that the object you wish to image will end up on the CCD chip.

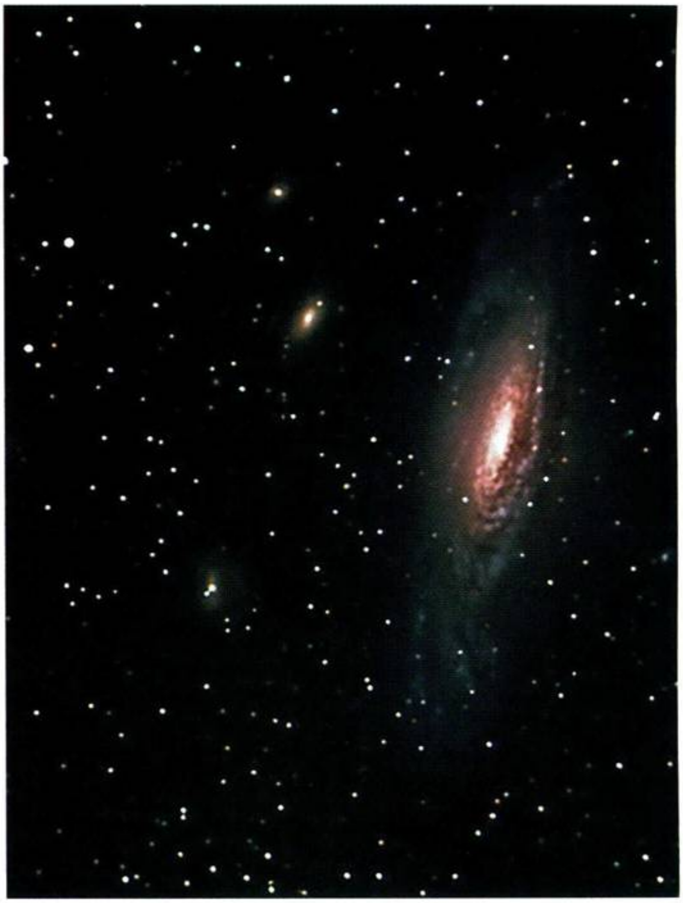
Focus

Select a bright star close to your target object and take a 1-second exposure. Because it's unfocused, the star you've chosen will appear as a disk. Use the telescope's electric focus to make an adjustment. Try a one-second press of the focus button either in or out. Take another exposure. If the disk gets larger, change the direction of focus. As the star shrinks to a sharper image, it will start to overexpose. Reduce the exposure time or select a dimmer star to make it easier to complete the focusing process. Programs such as *MaxIm DL* will read the star's brightness to help you find the best focus.

THE ROSETTE NEBULA (NGC 2237) in Monoceros was captured by the author with his Meade 5-inch f/9 APO refractor and a Finger Lakes Instrumentation Dream Machine CCD. The exposures were Hα = 10 minutes, R = 8 minutes, G and B = 10 minutes each.



THE WITCH HEAD NEBULA in Eridanus was imaged with a Meade 7-inch f/9 APO refractor. RGB exposures were 8, 10, and 10 minutes, respectively, using a Finger Lakes Instrumentation Dream Machine CCD camera.



THE GALAXY NGC 7331 in Pegasus was imaged with a Meade 16-inch f/10 LX200 and a Finger Lakes Instrumentation Dream Machine CCD camera. The exposures were L and R = 10 minutes each, G and B = 12 minutes each.

Shoot

Now that your camera is focused, center your target and take an 8-second exposure. Check the image placement on the CCD chip, make any final adjustments (use your scope's slowest slewing speed), and reshoot. Once you are satisfied with the composition, take a 1-minute exposure. If there is no trailing of star images, you may wish to increase the exposure. The accuracy of your mount's tracking will determine the maximum exposure. In alt-azimuth mode, the field of view will show some rotation after a few minutes. The amount depends on where the object is in the sky. If you wish to stack a number of exposures, *MaxIm DL* can assist you by derotating your images.

If your object is still too faint after a 1-minute exposure, you have two options to increase its brightness. One is to "bin" the CCD camera's image 2x2 using *MaxIm DL*. This combines the energy from four pixels into one "superpixel." (It also reduces the area of your image by a factor of four.) The second option is to use an f/6.3 or f/3.3 telecompressor. A shorter focal ratio produces a much brighter image, increases the overall field of view, and reduces the image size.

Film vs. CCD

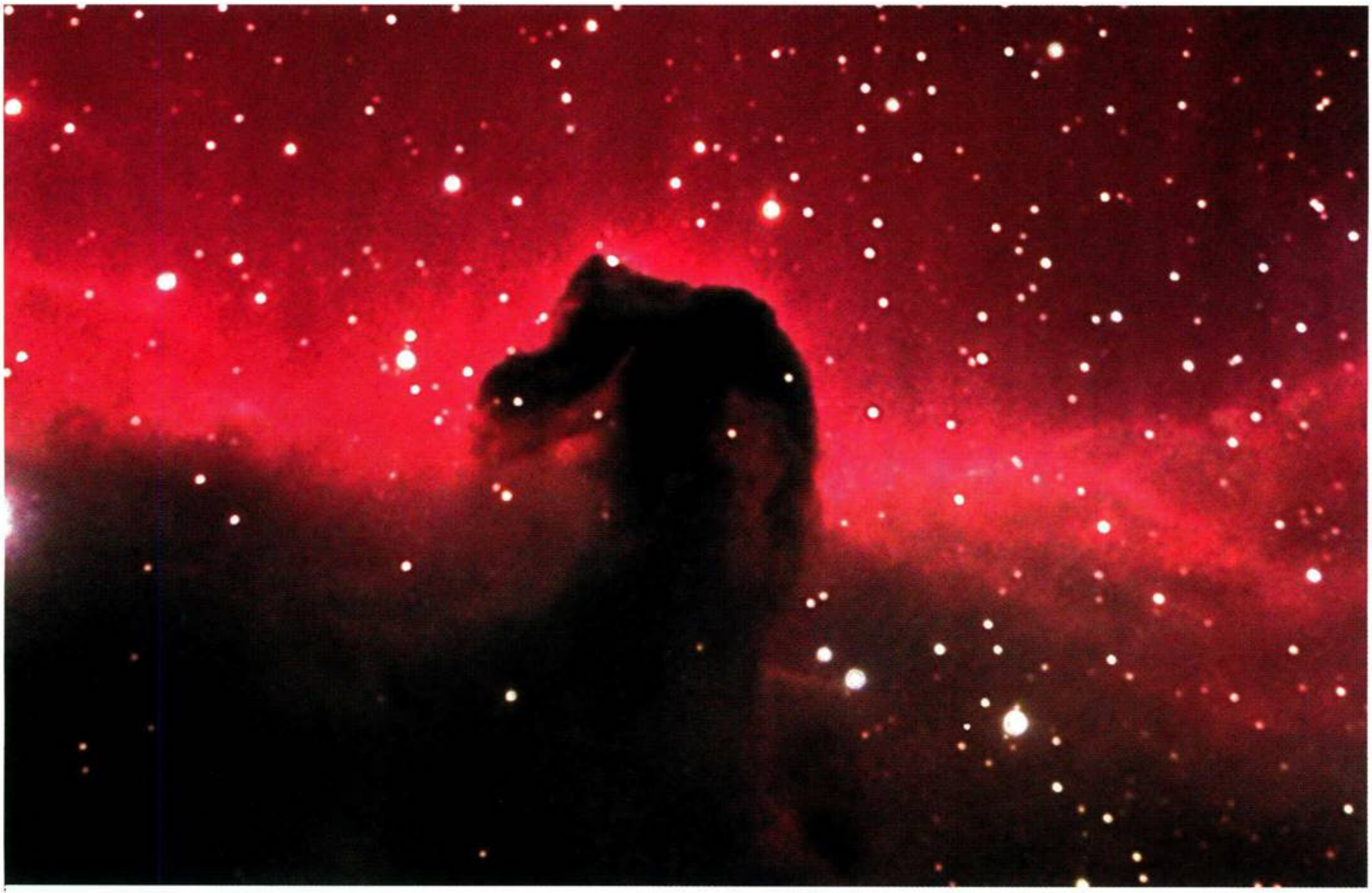
CCD imaging is an extension of film astrophotography except for the learning curve, which is much steeper. Using film can require as little as a properly aligned, stable telescope and a well-focused camera. To move into the CCD realm, you must be prepared to add a speedy computer with lots of storage capacity, a CCD camera, acquisition and image-processing software, and a host of connecting wires.

In fairness, I should admit that it's not necessary to go hog-wild on the family budget to get satisfying results. Black-and-white imaging is much simpler and provides wonderful payback for time spent.

When I used film (gas-hypered Kodak Technical Pan 2415), magnitude 17.5 stars were the faintest I could record with my 25-inch f/5 scope. Now I can confirm supernova discoveries fainter than 19th magnitude with 1-minute exposures using a 16-inch Meade LX200 at f/10.

Last summer, I wanted to tackle some extremely faint galaxies made famous by the Hubble Space Telescope. I chose the lensing galaxy cluster Abell 2218. A few high-mass objects that we can observe (in this case a galaxy cluster) in essence act like lenses, bending light from more distant objects that would be invisible otherwise. Abell 2218 is 2 to 3 billion light-years away, but the "lensed" light comes from objects 13 billion light-years distant. I wasn't certain what the result would be; however, my 30-minute exposure revealed lensing — and this from a telescope with a mirror only 16 inches in diameter!

For me, color CCD imaging requires as many as five separate images. I regularly use red, green, blue, clear (which produces an unfiltered image for "luminosity" data), hydrogen-alpha (Hα), or oxygen 3 (OIII) filters. I use several CCD cameras, including a Meade Pictor *1616XTE* with a Kodak 1024x1536 pixel chip and a Finger Lakes Dream Machine with a 1-inch square



THE HORSEHEAD NEBULA in Orion is one of the most famous of all dark nebulae. Also known as Barnard 33, the Horsehead is an area in space where cold gas and dust block the light from more distant stars. The author imaged this object with his Meade 16-inch f/10 LX200 and a Finger Lakes Instrumentation Dream Machine CCD camera. The exposures were Hα and R = 10 minutes each, G and B = 12 minutes each.

1024x1024 Site (Tectronics) chip. I also use an SBIG STV CCD camera for autoguiding. I typically use the following exposure times to compose a color image with my Dream Machine: R = 6 minutes; G = 8 minutes; B = 8 minutes; Hα = 10 minutes; and luminosity = 10 minutes.

Image processing with MaxIm DL

If I am using a CCD autoguider, I will usually take several 1- or 2-minute exposures and then "stack" them. I typically work with three 2-minute exposures in R, four 2-minute exposures in G, four 2-minute exposures in B, and two 1-minute exposures in L. I take the raw images and subtract dark frames as well as hot and cold pixels. (See the operation manual of your CCD camera for these techniques.) I then combine the images. This means, for example, that eight 1-minute L images become one single image. If I'm creating a color image I also combine the R, G, and B images. In *MaxIm DL*, I open *color* on the top menu and place the color images in their proper spots in the *combine color* box. If I've taken the images with an equatorially-mounted telescope, I then select *align* and *auto star matching*. (Images taken in alt-azimuth mode are handled differently; at this point it would be necessary to choose *2-star alignment* to correct for any field rotation.)

The aligned image will appear in the *preview image* box. Set the luminance weight to 80% and press *ok*. The color image will appear on the monitor, where you can process it using *filter* and *digital development* functions. I select *kernel low-pass*, a filter that flattens the image. The best demonstration for this process is an image of a globular cluster with an unresolved core. After using the low-pass filter, the image can be adjusted using the *screen stretch* box to show the individual stars in the core as well as the faint, outer stars.

To color balance the final image, use the *color* tab. Select *color balance* (and, if you wish, *color saturation*) and adjust to your taste. The final image should be saved as an unstretched ".fits" file and then re-saved as an 8-bit stretched ".tif" file for easy transfer to other programs that can only read 8-bit files.

Hα images

I process Hα images by combining two 2-minute red exposures with a 10-minute Hα image. This combined image will not overpower the blue and green images when a final color image is made. Mixing the Hα and the luminance together can enhance special objects. The California Nebula and North America Nebula both respond well to this process. Naturally, some experimentation is required.

Create an RGB image in *MaxIm DL* and stretch it to your preference. Save it as an 8-bit ".tif" file with *screen stretch*. Do the same with the Hα image. Select *process* on the task bar and *align* on the drop-down menu. Select *RGB*, *L*, and *Hα*, and click *ok*. Select *auto star matching* in the align mode and click *overlay all images*. Save the aligned images. ■

To learn more about CCD imaging, visit http://www.astronomy.com/toc

EQUIPMENT REVIEW

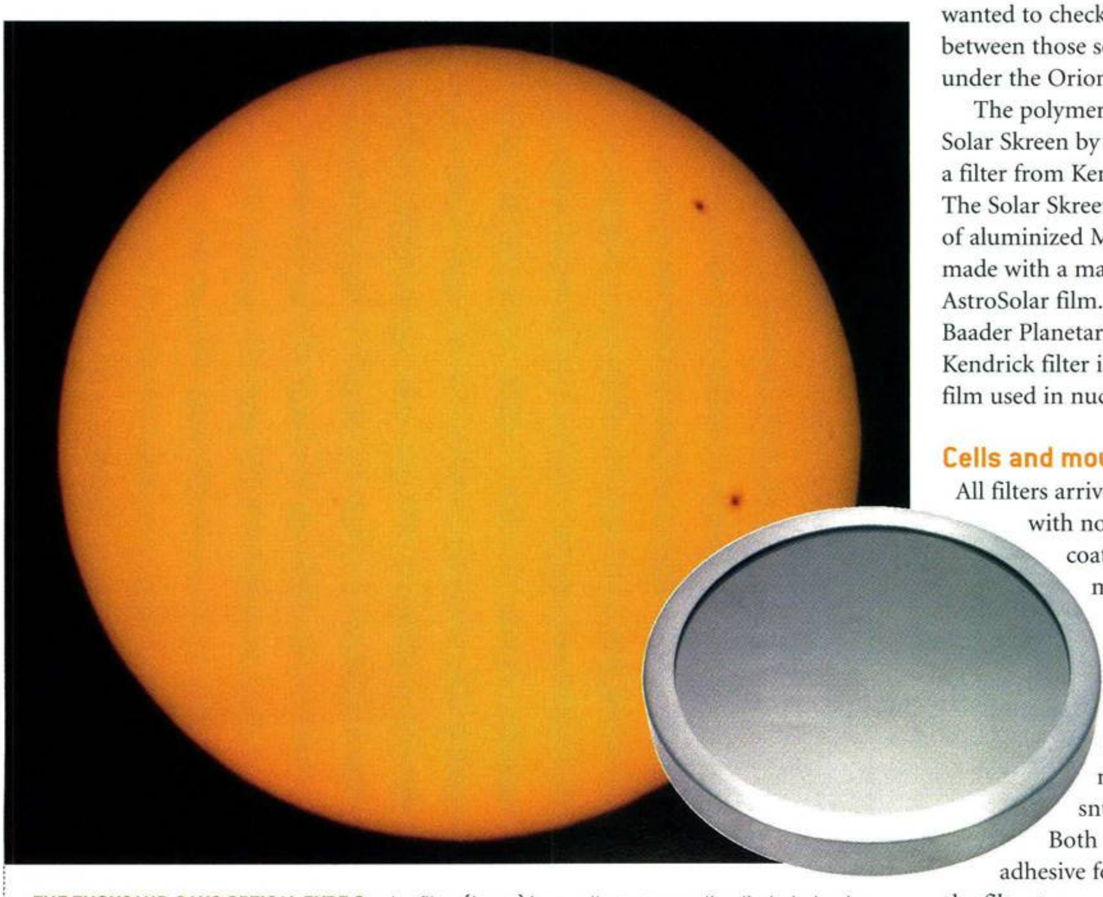
Discover the best way to observe our daytime star safely and with the greatest clarity.

/// BY ROD POMMIER

Selecting a solar filter

I began observing the Sun when I was 12. It's a dynamic and exciting object — and you don't need dark skies to see it. Safe solar observing does require special equipment, however. Foremost is a high-quality visual solar filter. Be sure to get one that fits securely over the front end of your telescope. Solar filters stop 99.999% of the Sun's light from entering the telescope. Such filters excel at blocking harmful infrared (heat) and ultraviolet radiation. As a bonus, views tend to be sharper because the telescope tube stays cool.

Two types of visible-light solar filters are currently available: mirror-like filters made of glass, and filters made of reflective polymer film. While glass filters may seem superior to their flimsy-looking polymer counterparts, some observers prefer the views through polymer filters. But which are better? To find out, I compared five solar filters side by side.



THE THOUSAND OAKS OPTICAL TYPE 2 solar filter (inset) is excellent at revealing limb darkening. Solar image taken November 23, 2002, with a Celestron C8 at f/10, Leica camera body, Kodak Gold 200 film, from Portland, Oregon. WILLIAM ZUBACK/ROD POMMIER

The filters

I used all filters full-aperture, mounted on my 8-inch f/10 Celestron Schmidt-Cassegrain telescope. The glass filters included a Type 2 from Thousand Oaks Optical, a Class A Identi-View from JMB, Inc., and an Orion Solar Filter from Orion Telescopes and Binoculars. (The Orion filter is actually produced by JMB, but I wanted to check for any differences between those sold directly and those sold under the Orion name. I found none.)

The polymer filters I tested included a Solar Skreen by Roger W. Tuthill, Inc., and a filter from Kendrick Astro Instruments. The Solar Skreen is made with two layers of aluminized Mylar. The Kendrick filter is made with a material called Baader AstroSolar film. (The supplier is the Baader Planetarium in Germany.) The Kendrick filter is not simple Mylar but a film used in nuclear and particle physics.

Cells and mountings

All filters arrived in excellent condition with no pinholes in their metallic coatings. The glass filters were mounted in aluminum cells. As expected, the JMB and Orion filters appeared identical, each bearing a cell with a blue stripe. Each had a foam-rubber lining to ensure a snug fit over the telescope. Both also came with additional adhesive foam rubber pads to help fit the filter to any telescope with a slightly smaller tube diameter. It's important for any solar filter to attach securely to the tube or it may fall off (or be knocked or blown off) in use — a catastrophic event for anyone observing at the time.

The Thousand Oaks filter had no inner-cell lining, but it still fit securely. The Tuthill filter was housed in a cell of plastic plumbing fittings. It also fit securely right out of the box. The Kendrick filter was mounted inside a painted aluminum cell that attached securely to the telescope with three nylon thumbscrews.

First views

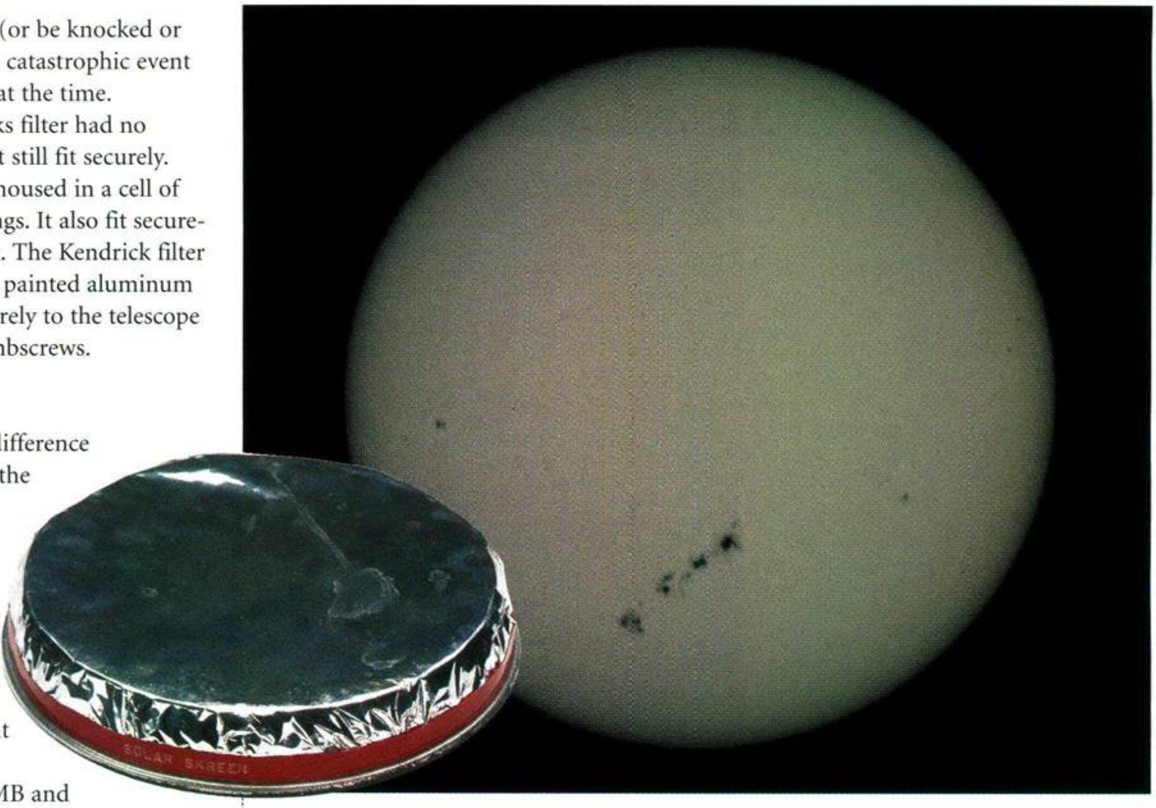
The most noticeable difference among the filters was the apparent color of the Sun. Its visible layer, the photosphere, looked yellow-orange through the Thousand Oaks filter (the most striking of the colors) and light yellow with a hint of orange through the JMB and Orion filters. The photosphere appeared pale white through the Kendrick filter and pale blue through the Tuthill filter.

The background sky was black through all the filters except the Tuthill, through which it looked bright blue. The Tuthill filter also exhibited the most scattering of light. These differences notwithstanding, all the filters performed remarkably well.

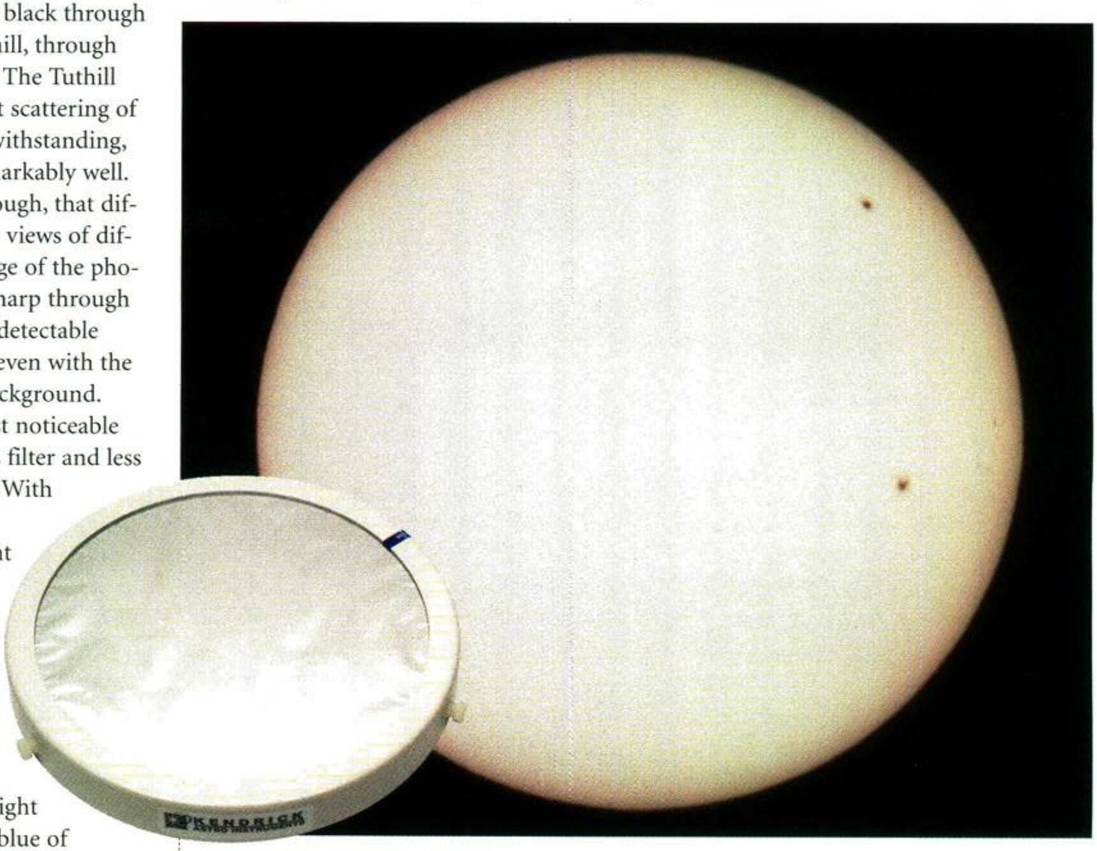
I found, interestingly enough, that different filters provided better views of different solar features. The edge of the photosphere appeared equally sharp through all the filters; there were no detectable color fringes. This was true even with the Tuthill filter's bright blue background.

Limb darkening was most noticeable through the Thousand Oaks filter and less obvious through the others. With the Kendrick filter, the limb darkening appeared as a faint brown tint. I initially thought this was a color fringe, but this filter also shows darker solar features as shades of brown.

Faculae looked best through the Tuthill filter. The contrast between the bright blue faculae and the deeper blue of the photosphere near the limb made the faculae stand out. They were least visible through the Kendrick filter: Faculae



THE SOLAR SKREEN by Roger W. Tuthill, Inc. [inset] uses two sheets of optical-quality Mylar to filter the Sun's harmful radiation. Solar image taken June 8, 1991, with a Celestron C8 at f/10, Leica camera body, Kodak Gold 100 film, from New York City. WILLIAM ZUBACK/ROD POMMIER



THE BAADER ASTROSOLAR FILTER from Kendrick Astro Instruments [inset] is made of a material used in nuclear and particle physics. Solar image taken September 3, 1989, with a Celestron C8 at f/10, Leica camera body, Kodak Gold 100 film, from New York City. WILLIAM ZUBACK/RICK DILSIZIAN

THE JMB IDENTI-VIEW AND ORION SOLAR FILTERS (inset) are both produced by JMB, Inc. Solar image taken November 23, 2002, with a Celestron C8 at f/10, Leica camera body, Kodak Gold 200 film, from Portland, Oregon. WILLIAM ZUBACK/ROD POMMIER

/// WHAT YOU CAN SEE

Celestial objects are more exciting and enjoyable when we understand what we're observing. This is especially true of the Sun. The solar filters reviewed here show five of the Sun's features easily.

The first is the solar disk or photosphere. From Earth, the Sun appears to have a sharp edge, but this is an illusion. If we could travel closer to the Sun, we'd see its edge is actually a hazy layer of gas.

This layer of gas produces the second feature — limb darkening. The photosphere appears noticeably darker at the edge, or limb, of the Sun. At the center of the visible disk, radiation reaches us directly from deeper, hotter, and brighter layers. Near the limb, we see radiation only from higher, cooler, and therefore dimmer, layers of gas.

Faculae, the third feature, are glowing, irregular clouds of hot gas within the photosphere. Observers generally see faculae near the limb, where the darkening effect provides enough contrast to make them visible.

Sunspots are the fourth and most conspicuous feature through a visual filter. Each has an irregular dark center (the umbra) surrounded by a zone of lighter radiating lines (the penumbra). Most sunspots are larger than Earth. They appear dark because they are much cooler than the surrounding photosphere. But this darkness is relative. If the rest of the Sun were to disappear, the average sunspot would bathe Earth in more light than the Full Moon.

Granulations are the fifth feature easily visible with a telescope and solar filter. Giving the photosphere a mottled appearance, granulations are convective cells of churning, hot gas, each about 600 miles across. In each granule, hot gas rises to the surface, cools, and sinks over a period of 10 to 15 minutes. You'll see granulations only under the best seeing conditions. – R. P.

appeared a lighter shade of white against the photosphere and around the limb.

I examined sunspots at 77x and 167x. At low power, I saw sharp contrasts between sunspots and the photosphere through all the filters. Details also were visible in the penumbrae (less-dark areas that surround the inner, darker umbrae of sunspots) during steady moments.

Sunspots showed up in color through the Kendrick filter. Umbrae were dark chocolate brown, and penumbrae were the color of coffee stains on white fabric. This effect contrasted with the photosphere and gave the impression that I was seeing the Sun's true color rather than looking through a filter that gave a colored effect.

At high power, the Kendrick filter showed more detail in both umbrae and penumbrae than the other filters. Perhaps the two surfaces in the glass filters and the second sheet of Mylar in the Tuthill filter scatter enough light to blur details that appear so crisp through the single-layer Kendrick filter. The Tuthill filter offered the second-best view of sunspots, while the others tied for third.

The Kendrick filter showed granulations best, and they were striking during moments of good seeing. Granulations were also distinctive through the Tuthill filter. The glass filters all showed this feature clearly, but seeing it at all depended on the steadiness of the atmosphere.

The Thousand Oaks filter yielded the darkest image. While this was pleasing at low power, it made the high-power views

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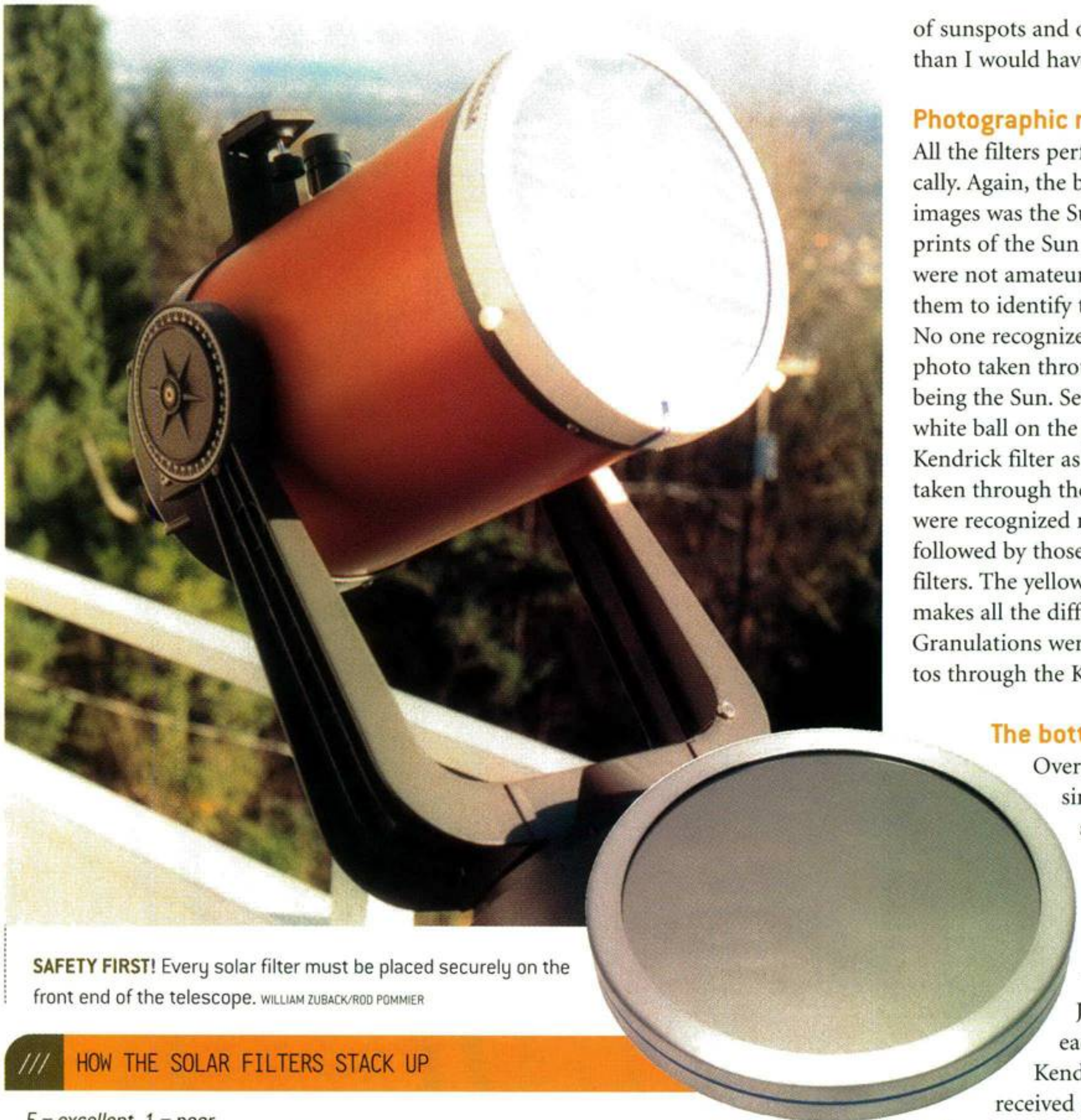
Rod Pommier *is a surgeon at Oregon Health & Science University. He avidly pursues visual astronomy and astrophotography under the dark skies of Oregon.*



SAFETY FIRST! Every solar filter must be placed securely on the front end of the telescope. WILLIAM ZUBACK/ROD POMMIER

/// HOW THE SOLAR FILTERS STACK UP

5 = excellent, 1 = poor

Feature	Thousand Oaks	JMB	Orion	Tuthill	Kendrick
photosphere edge	5	5	5	5	5
limb darkening	5	4	4	4	3
faculae	4	4	4	5	3
sunspots (low magnification)	5	5	5	5	5
sunspots (high magnification)	3	3	3	4	5
granulations	3	3	3	4	5
light scattering	5	5	5	4	5
image brightness	4	5	5	5	5
total score	34	34	34	36	36

of sunspots and other features dimmer than I would have liked.

Photographic results

All the filters performed well photographically. Again, the biggest difference in the images was the Sun's color. I showed prints of the Sun to several people who were not amateur astronomers and asked them to identify the object in the picture. No one recognized the blue ball in the photo taken through the Tuthill filter as being the Sun. Several people mistook the white ball on the photograph through the Kendrick filter as the Moon. The photos taken through the Thousand Oaks filter were recognized most often as the Sun, followed by those through the JMB/Orion filters. The yellow-orange color apparently makes all the difference for recognition. Granulations were most visible in the photos through the Kendrick filter.

The bottom line

Overall, the filters received similar ratings, with two scoring only slightly higher (see the table at left). The Kendrick and Tuthill filters both scored 36 points, while the Thousand Oaks, JMB, and Orion filters each scored 34 points. The Kendrick filter, however, received more top scores than any other. This indicates that polymer filters may have a slight advantage over those made of glass. I give the polymer filters superb ratings and the glass filters excellent ratings.

Your choice of filter, therefore, depends on what you want to see. If you want granulations or detail in sunspots at high power, choose either the Kendrick or the Tuthill filter. For accentuating faculae, the Tuthill filter worked best. If you want to see the limb-darkening effect, try a Thousand Oaks or a JMB/Orion filter. If you want to photograph the Sun and have ordinary people recognize the photos as the Sun, you might choose a Thousand Oaks or JMB/Orion filter over a Kendrick or Tuthill. For research photography, the opposite might hold true.

Whatever your final choice, any of these excellent filters will provide detailed views and photographs of our nearest star. ◼

Drawing on 43 eyepieces, 10 manufacturers, and three telescopes, *Astronomy* guides you to the equipment that will make your observing successful. /// BY STEPHEN J. EDBERG

Choosing an eyepiece

"What eyepieces should I use?"

All amateur astronomers ask this question at some stage of observing. The view through a telescope — even a small, department-store refractor — improves with better eyepieces. But what does "better" mean? *Astronomy* asked several eyepiece vendors to supply representative eyepieces with focal lengths around 10mm and 24mm. Under average suburban skies, these focal lengths work well for upper and lower "medium" magnification of celestial objects. Under the unsteady Southern California skies where this review took place, higher magnifications don't provide views that are substantially more detailed.

Loaded down with 43 eyepieces from 10 manufacturers as well as my own personal favorites from a bygone optical-era, I set comparison criteria and began testing. All observers develop biases toward what's important when viewing the sky through a telescope. These preferences might include a wide field of view, pinpoint star images, planetary contrast, or freedom from pincushion distortion. For this review, I looked at apparent field of view, eye relief, star image quality, distortion, planetary contrast, and glare or reflections. When

MEADE
ULTRA WIDE
WIDE ANGLE
MULTI-COATED
MEADE SUPER
WIDE ANGLE 32mm
MULTI-COATED
CELESTRON
X-Cel 25mm
PLössl 25mm
PLössl 9mm
Series 500 PLÖSSL
Series 500 PLÖSSL 10mm
UNIVERSITY
SUPER ER 25mm MC
KÖNIG
Multi-Coated
Digitec Optical
PLÖSSL 9mm
SCOPETRO
PLÖSSL 12

selecting eyepieces, observers ideally should use their own telescope and make comparisons while viewing a familiar or favorite object and swapping between eyepiece A and eyepiece B, looking for differences. It's almost impossible to judge eyepieces without doing this type of side-by-side comparison.

Sometimes there aren't differences between eyepieces, and you'll see in the comparison charts (pages 112–113) that most of the eyepieces performed extremely well. The real value of an exceptional eyepiece comes when it allows you to make an observation that pushes the envelope of what you thought was possible.

The telescopes

A telescope's optical "speed" defines the angle of the cone of light received by the eyepiece. The shape of the light cone affects the view through the eyepiece. Telescopes with a small focal length-to-aperture ratio are fast and have low f/ratios. Slower telescopes have larger f/ratios and narrower cones of light. To account for these variations, I tried all the eyepieces on three separate telescopes that are listed in the comparison charts: a Tele Vue-NP101 101mm apochromatic refractor (f/5.4), a 10-inch Cave Astrola Newtonian (f/6.8), and a Celestron 5-inch Schmidt-Cassegrain (f/10). The eyepieces were tested on both Jupiter (which conveniently was passing the Beehive Cluster) and the Whirlpool Galaxy (M51).

The criteria

Apparent field of view describes how wide an area appears to the eye through the eyepiece. It's not an angle on the sky. Rather, it's a measure of how much of your eye's field of view is filled. A narrow field of view is like looking through a tunnel, and a wide one can seem like a porthole on the universe. The specification is usually available from the vendor, but testing the eyepiece yourself is easy. Just hold the eyepiece up to your eye as though you were looking through a scope and notice how large a white spot you see. You can even compare eyepieces by putting one in front of each eye. I classified eyepiece fields of view as wide (around 80°), medium (around 65°), and narrow (around 50°). The Zoom eyepiece by Meade has a very narrow and slightly variable field of view, with a value in the upper 40° range.

Eye relief is the maximum distance between an observer's eye and the eyepiece where the full field of view remains visible. This criterion is important to people who choose to wear eyeglasses while observing. Many vendors claim their eyepieces have sufficient eye relief for eyeglass wearers, but only the Celestron X-Cel 10mm worked with mine; I used an old-fashioned, large-frame pair to test eye relief. The Tele Vue Radian 10mm gets an honorable mention for providing almost the full field of view with my glasses on. Observers with smaller glasses worn closer to their eyes may find additional eyepieces that are usable. Short focal length eyepieces generally have less eye relief than longer focal length eyepieces.

Star image quality defines the degree to which stars appear as pinpoints of light.

CELESTRON X-Cel 12.5
CELESTRON X-Cel 10mm
ORION SUPERWIDE 22mm
Nagler type 5 26mm
Nagler type 6
Nagler type 4 12mm
ORION Expanse
Ultrascopic
ORION
Tele Vue 11mm PLOSSL
Radian 12
10mm Tele Vue

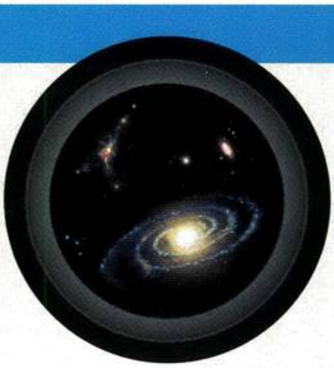
/// Short focal length eyepieces

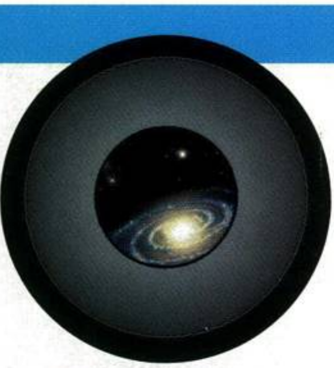
MANUFACTURER	EYEPIECE	APPARENT FoV	EYE RELIEF	STAR IMAGE QUALITY [f/5.4]				STAR IMAGE QUALITY [f/10]				REFLECTIONS OR GLARE	DISTORTION
				CENTER	0.5 RADIUS	EDGE	CONTRAST	CENTER	0.5 RADIUS	EDGE	CONTRAST		
Celestron	Ultima 10mm	Narrow	No	Point	Point	Extended	Good	Point	Point	Extended	Fair	No	None
	X-Cel 10mm	Narrow+	No	Point	Extended	Extended	Good	Point	Point	Extended	Good	Reflection	None
	Omni 9mm	Narrow	No	Point	Point	Extended	Good	Point	Point	Extended	Fair	No	None
Digitec	Plössl 9mm	Narrow	No	Point	Point	Extended	Good	Point	Point	Extended	Good	No	None
Hardin Optical	Astrola Plossl 9mm	Narrow	No	Point	Point	Extended	Good	Point	Point	Extended	Good	No	None
Meade	[1]Ultra Wide 8.8mm	Wide	No	Point	Point	Extended	Good	Point	Point	Point	Fair	No	None
	Super Plössl 9.7mm	Narrow	No	Point	Extended	Extended	Good	Point	Point	Extended	Poor	No	Slight
	Super Wide 13.8mm	Medium	No	Point	Extended	Extended	Good	Point	Extended	Extended	Good	No	None
	[2]Zoom 8-24mm	Very Narrow	No	Point	Point	Extended	Fair	Point	Point	Point	Poor	See note	None
Orion	[3]Expanse 9mm	Medium	No	Point	Point	Extended	Good	Point	Point	Extended	Fair	No	None
	HighLight Plössl 10mm	Narrow	No	Point	Point	Extended	Good	Point	Point	Extended	Good	No	None
	Lanth SuperWide 8mm	Medium	No	Point	Point	Slightly Ex.	Good	Point	Point	Point	Fair	No	None
	[4]Ultrascopic 10mm	Narrow	No	Point	Point	Extended	Good	Point	Point	Extended	Good	No	None
Owl Services	Plössl 10mm	Very Narrow	No	Point	Point	Extended	Very Good	Point	Point	Extended	Poor	No	None
ScopeTronix	Plössl 12mm	Narrow	No	Point	Point	Extended	Good	Point	Point	Extended	Poor	No	None
Siebert Optics	[5]13mm	Narrow+	No	Point	Point	Extended	Good	Point	Slightly Ex.	Extended	Fair	No	None
Tele Vue	Nagler type 4 12mm	Wide	No	Point	Point	Extended	Good	Point	Point	Point	Good	No	None
	Radian 10mm	Wide-	Almost	Point	Point	Point	Good	Point	Point	Point	Fair	No	None
	Nagler type 6 9mm	Wide	No	Point	Point	Slightly Ex.	Good	Point	Point	Point	Good	No	None
	Plössl 11mm	Narrow	No	Point	Point	Extended	Good	Point	Point	Extended	Good	No	None
University	Ortho 9mm	Narrow-	No	Point	Point	Extended	Good	Point	Extended	Extended	Good	No	None
Old Favorites	Steve's Clave 8mm	Narrow	No	Point	Point	Extended	Good	Point	Point	Extended	Good	No	None
	Steve's Vixen Lanthanum 10mm	Narrow	No	Point	Point	Extended	Good	Point	Point	Point	Good	No	None

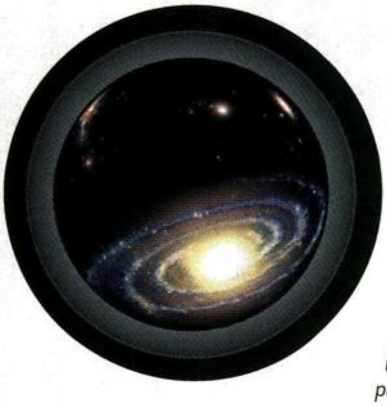
COMMENTS: [1]Eyecup larger than eyesocket; can't see full FoV. /// [2]Reflection at 24mm with f/10 telescope. /// [3]Excellent eye relief; FoV edge soft and colored. /// [4]Susceptible to condensation. Tight fit in one eyepiece holder. /// [5]Susceptible to condensation. Metal not nicely finished.

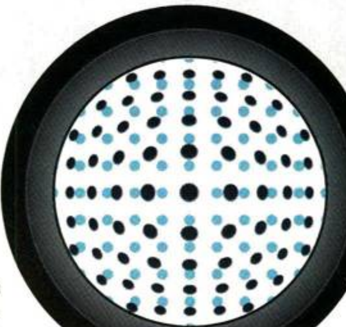
/// OPTICAL DEFECTS

starfield [actual sky]

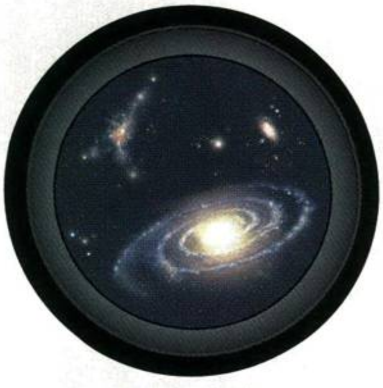

wide apparent field of view


narrow apparent field of view




pincushion distortion

[non-distorted positions in blue]


poor contrast

/// Long focal length eyepieces

		APPARENT	EYE	STAR IMAGE QUALITY [f/5.4]				STAR IMAGE QUALITY [f/10]				REFLECTIONS	
MANUFACTURER	EYEPIECE	FoV	RELIEF	CENTER	0.5 RADIUS	EDGE	CONTRAST	CENTER	0.5 RADIUS	EDGE	CONTRAST	OR GLARE	DISTORTION
Celestron	[1]Axiom 23mm	Medium	No	Point	Point	Extended	Good	Point	Extended	Extended	Good	No	Some
	[2]X-Cel 25mm	Narrow+	Barely	Point	Point	Extended	Good	Point	Extended	Extended	Good	No	None
	Omni 25mm	Narrow	No	Point	Point	Extended	Fair	Point	Point	Extended	Good	No	None
Digitec	Plössl 25mm	Narrow	No	Point	Point	Extended	Fair	Point	Extended	Extended	Fair	No	None
Hardin Optical	Astrola Plössl 25mm	Narrow	No	Point	Point	Slightly Ex.	Good	Point	Point	Extended	Good	No	Slight
Meade	Super Plössl 26mm	Narrow	No	Point	Point	Extended	Fair	Point	Point	Extended	Good	Yes	None
	Super Wide 24.5mm	Medium	No	Point	Slightly Ex.	Extended	Fair	Point	Extended	Extended	Good	No	None
	[3]Zoom 8-24mm	Very Narrow	No	Point	Point	Point	Good	Point	Point	Point	Good	Reflection	None
Orion	[4]Expanse 20mm		No	Point	Extended	Extended	Good	Point	Point	Extended	Good	No	None
	[5]HighLight Plössl 26mm	Medium	No	Point	Point	Slightly Ex.	Fair	Point	Extended	Extended	Fair	No	None
	[6]Lanth SuperWide 22mm	Narrow+	No	Point	Point	Point	Fair	Point	Point	Extended	Good	No	None
	Ultrascopic 25mm	Medium	No	Point	Point	Extended	Poor	Point	Point	Extended	Good	No	None
		Narrow											
Owl Services	Plössl 25mm		No	Point	Point	Slightly Ex.	Poor	Point	Point	Extended	Good	No	None
		Narrow											
ScopeTronix	Plössl 25mm		No	Point	Point	Slightly Ex.	Fair	Point	Point	Extended	Good	No	None
		Narrow											
Siebert Optics	[7]22.5mm		No	Point	Point	Slightly Ex.	Good	Point	Extended	Extended	Fair	No	None
		Narrow											
Tele Vue	Nagler type 5 26mm		No	Point	Point	Slightly Ex.	Poor	Point	Point	Extended	Good	No	None
	[8]Nagler type 4 22mm	Wide	No	Point	Point	Slightly Ex.	Poor	Point	Point	Extended	Fair	No	None
	Panoptic 27mm	Wide	No	Point	Point	Slightly Ex.	Poor	Point	Extended	Extended	Fair	No	None
	Panoptic 24mm	Medium	No	Point	Point	Slightly Ex.	Poor	Point	Point	Extended	Fair	No	Some
	Plössl 25mm	Medium	No	Point	Slightly Ex.	Extended	Poor	Point	Point	Extended	Good	No	Some
		Narrow											
University	[9]Konig 24mm		No	Point	Slightly Ex.	Extended	Poor	Point	Point	Extended	Fair	No	None
	[10]Super E. 25mm	Medium-Narrow+	No	Point	Point	Extended	Poor	Point	Point	Extended	Good	No	None
Old Favorites	[11]Steve's Clave 25mm		No	Point	Slightly Ex.	Extended	Poor	Point	Extended	Extended	Good	No	None
	Steve's Vixen	Narrow	No	Point	Point	Slightly Ex.	Poor	Point	Point	Extended	Good	No	None
	Lanthanum 25mm	Narrow											

COMMENTS: [1]Eyeshade, not eyecup. /// [2]No distortion when tested on fence. Surprisingly narrow field. /// [3]No distortion when tested on fence. Nice images. Zoom not parfocal. /// [4]No distortion when tested on fence. Small diameter with Medium FoV. /// [5]Eyeshade, not eyecup. /// [6]No distortion when tested on fence. /// [7]Metal isn't nicely finished. Soft FoV edge. Adjustable hard eyecup. /// [8]Adjustable hard eyecup. /// [9]No eyecup. /// [10]No eyecup. /// [11]No eyecup.

Often, stars appear as elongated disks near the field's edge and sometimes even closer to the center. I judged image quality in three locations: at the center of the field, halfway to the edge, and near the edge. In a few eyepieces, images classified as "point" may have a minimal amount of elongation that is unnoticeable except under perfect observing conditions. Why do pointlike images matter? To see the faintest objects, the light should be concentrated into the tiniest spot possible. Using back-and-forth comparisons of eyepieces in good seeing conditions will make discerning star image quality easier.

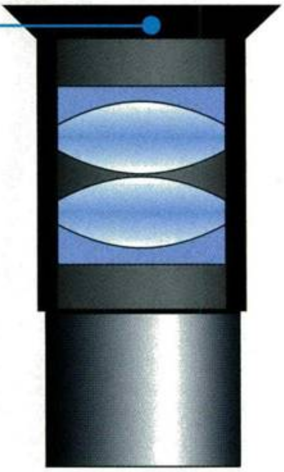
Pincushion distortion, which geometrically warps an image, is most noticeable to observers who like to sweep the sky. Eyepieces that distort show stars following curved paths across the field of view and cause pinpoint stars to have distorted spacings (although this is unnoticeable to most people). Extended objects viewed through such eyepieces will look different depending on where they are in the field of view. Sky-sweepers looking for objects or trying to find comets may find pincushion distortion disturbing. My "sweep" tests of the sky revealed pincushion distortion in a few eyepieces. Careful examination of a chain-link fence in daylight showed pincushion distortion in almost the entire longer focal length group. Happily, while slight pincushion distortion is present in some eyepieces, it is hardly noticeable. This is a wonderful change from the eyepieces of just a few years ago.

Contrast characterizes how much light is scattered by the optics. When light in an optical system gets slightly "off-course," the background gets lighter and the objects appear fainter. Contrast is extremely important to planetary observers looking for subtle detail. Long focal length eyepieces that showed Jupiter's belts at low power in the short f/ratio telescope were particularly impressive. An image with outstanding contrast can be ruined by internal reflections and glare. I noticed some minor reflections in the Meade Zoom and Super Plössl 26mm, the Celestron X-Cel 10mm, and the Siebert Optics 13mm.

Additional considerations

Manufacturers often note that a particular series of eyepieces is "parfocal." This means that if you focus one eyepiece and then exchange it for another member of the same group, the second eyepiece will also be in focus. It's a nice idea, but none of the pairs I tested was precisely parfocal, although an adjustable ring permits the Siebert Optics pair to be made parfocal.

"Parfocalization" is a convenience, but not a necessity. Experienced observers always refocus after an eyepiece change. Our eyes continuously change as we use them, so refocusing is a good observing practice, although fewer turns of the focusing knob are welcome. Most of the eyepiece models advertised as parfocal came reasonably close to expectations, although the Nagler eyepieces required considerable refocusing.

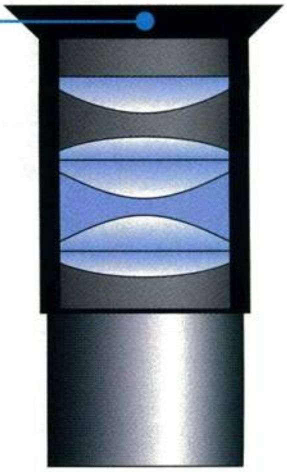


Plössl

number of elements: 4–5
apparent field: 50° to 55°

pros:
- low cost
- eye relief is $\frac{8}{11}$ the focal length
- minimal optical aberrations

cons:
- internal reflections

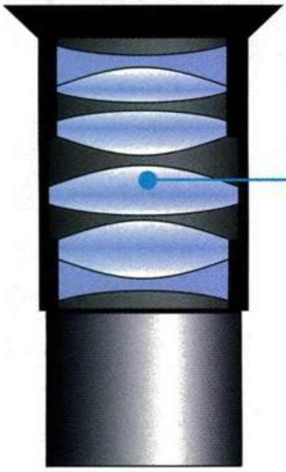


Orthoscopic

number of elements: 4
apparent field: 45° to 50°

pros:
- excellent contrast
- minimal chromatic aberration
- minimal field curvature

cons:
- some internal reflections

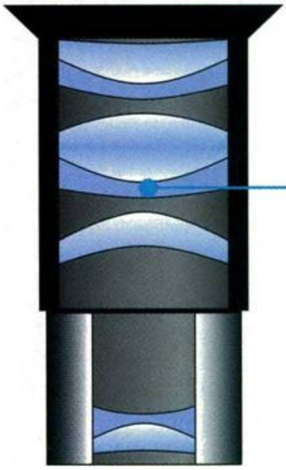


Panoptic

number of elements: 6
apparent field: 68°

pros:
- eye relief is $\frac{17}{25}$ the focal length
- large true FoV

cons:
- high price
- edge of field has pincushion distortion

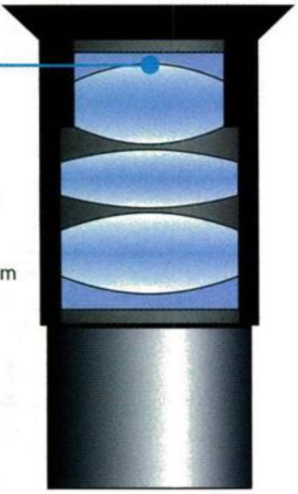


Nagler

number of elements: 6–8
apparent field: 82°

pros:
- huge apparent FoV
- no optical aberrations
- nice contrast

cons:
- high price

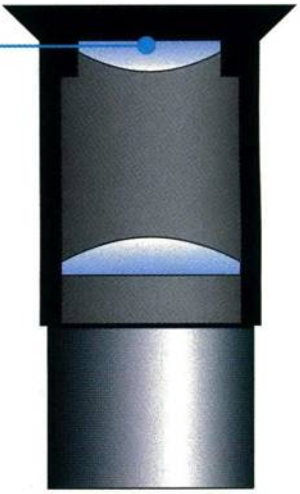


5-element Erfle

number of elements: 5
apparent field: 60° to 70°

pros:
- low cost
- minimal chromatic aberration
- minimal field curvature

cons:
- sometimes exhibit astigmatism at field edge

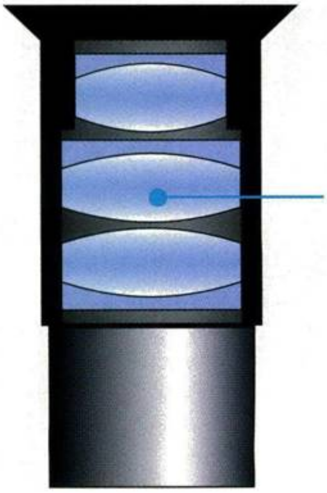


Ramsden

number of elements: 2
apparent field: 25° to 30°

pros:
- lightweight

cons:
- moderate chromatic aberration
- moderate field curvature
- small apparent FoV

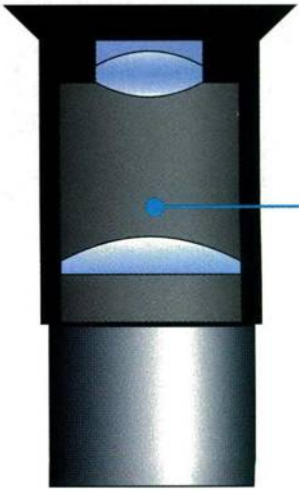


6-element Erfle

number of elements: 6
apparent field: 60° to 70°

pros:
- low cost
- minimal chromatic aberration
- minimal field curvature

cons:
- sometimes exhibit astigmatism at field edge



Kellner

number of elements: 3
apparent field: 40° to 45°

pros:
- very low cost
- good eye relief

cons:
- some chromatic aberration
- some field curvature

/// CONTACT INFORMATION

Celestron
2835 Columbia Street
Torrance, CA 90503
[t] 310.328.9560
[f] 310.212.5835
[w] www.celestron.com

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Wantagh, NY 11793
[t] 888.327.5759
[e] digitec@optonline.net
[w] www.digitecoptical.com

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[t] 800.394.3307
[e] telescopeshop@hardin.optical.com
[w] www.hardin.optical.com

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Other items to note include eyecups and lens caps. Most of the eyepieces came with eyecups. Eyecup styles range from short, rubber or adjustable metal ones to side-only eyeshades. Some can (and should be) folded down to their minimum height, while others can be used "as is." And watch out for an eyepiece that doesn't fit your eye socket — you might not ever be able to see the full field of view with it. Many of the eyepieces reviewed came either with covers for each end of the eyepiece or a storage canister. These nice additions help keep dust off hard-to-clean and easily damaged optics. The eyepieces' covers ranged from convenient to ill-fitting, with some even pulling off the rubber eyecup when the cap was removed. You wouldn't select an eyepiece based on its eyecups or lens caps, but you might want to make changes to these features after purchase.

Selecting for yourself

It's important to get out with your telescope and find the right eyepieces for your observing. All the eyepieces tested are acceptable or better than acceptable. You have to decide if the improvements in your overall viewing are worth the sometimes premium prices you have to pay. Compare eyepieces owned by your friends or members of a local astronomy club. There may be a great variety available for comparison testing. You'll get the most enjoyment from your nights under a clear and steady sky with eyepieces selected through your own (hopefully satisfying) testing. Be patient and careful in your selection, and then enjoy the view. ■

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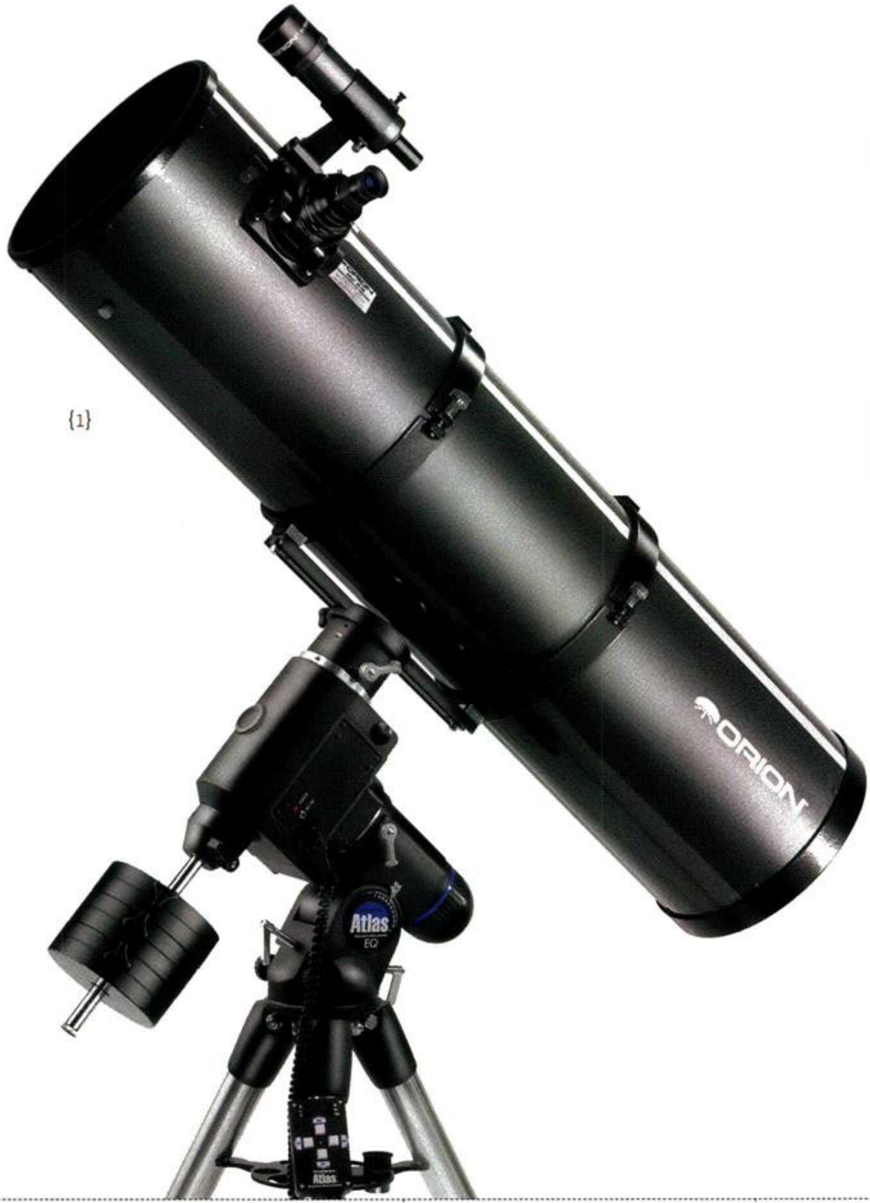

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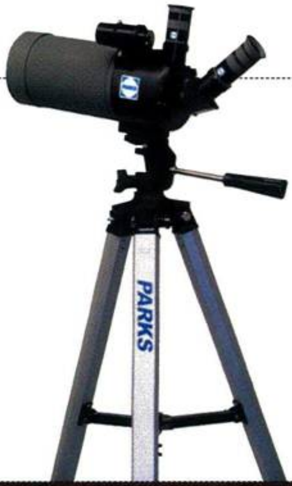

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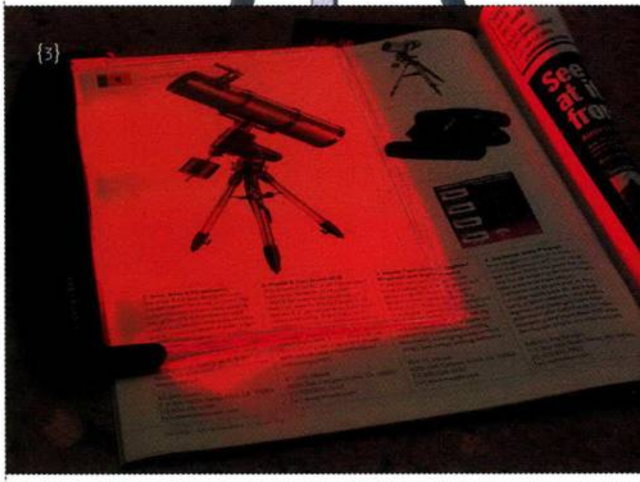

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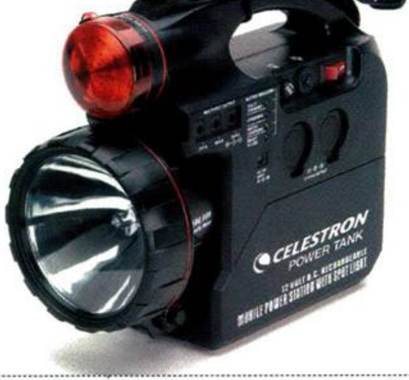

1. Orion Atlas 10 EQ Reflector

If you're trying to rope elusive quarry like the Horsehead Nebula, you're going to need a big lasso. This 10-inch, 108-pound package fits the bill. With low-expansion glass and a well-ventilated primary cell, the f/4.7 scope minimizes heat-induced distortions. Amenities include a 2" focuser, a 9x50 finder, two Sirius Plössl eyepieces, and an equatorial mount with a dual-axis stepper motor drive.

$1,299; Orion
P. O. Box 1815
Santa Cruz, CA 95061
[t] 800.447.1001
[w] www.telescope.com

2. Parks Jovian 90 WP

If portability is a priority, this 90mm, f/13 Maksutov-Cassegrain could be the telescope for you. Nitrogen in the optical tube prevents the formation of fog on the optics, and in the event of an unexpected downpour, rubber armoring keeps the multi-coated mirrors out of harm's way. A 26mm Super Plössl eyepiece, a flip-mirror, and an 8x21 erect-image finder scope come standard.

$399.95; Parks Optical
P. O. Box 716
Simi Valley, CA 93062
[t] 805.522.6722
[w] parksoptical.com

3. Red LED LightWedge reading light

This new gizmo puts the "fun" in functional. At the touch of a button, two LEDs illuminate the edge of a clear acrylic panel, bathing a book or star chart with one of two intensities of red light that won't destroy dark-adapted vision. The LightWedge runs on four AAA batteries that last 40 hours, and the LEDs will never burn out. The 6.75" by 9.25" reading aid weighs just 8.5 ounces.

$44.95; LightWedge
Zero Washington Street
Nantucket, MA 02554
[t] 877.777.9334
[w] www.lightwedge.com

4. Celestron Power Tank

Keep your telescope's motor running with this rechargeable power supply. The Power Tank features two 12-volt DC output ports and an adapter for a car's cigarette lighter; 3-, 6-, and 9-volt outputs for accessories; an 800,000 candlepower halogen spotlight; and a small red light to protect your night vision. Also included are a booster terminal, a circuit breaker, and an AC adapter.

$79.95; Celestron
2835 Columbia Street
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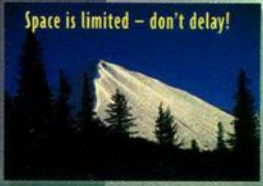
[w] www.celestron.com

Join *Astronomy* Magazine in Alaska for a

Northern Lights Tour

March 12-20, 2004

Astronomy magazine



Chase the colorful curtains of the aurora borealis through Alaska's interior with *Astronomy* Magazine. Along with catching one of the most spectacular views of the night sky, you will experience the magnificent vistas of a great, unspoiled wilderness.

Our experience begins in Chena Hot Springs, 60 miles from Fairbanks, and far from light pollution. The evening aurora should produce an impressive show as solar activity is expected to be high in March 2004. During the day you can take advantage of a horse-drawn sleigh ride, a dog sled ride and a sunset snow-monkey ride to the top of the mountain. Or relax in the world famous hot springs.

The adventure continues with three nights in downtown Fairbanks at the Springhill Suites Inn. You can arrange to shop, downhill ski, or simply curl up with a good book.

The breathtaking scenery is guaranteed to put you on sensory overload. Whatever your choices for the daylight and evening hours, pack your warm clothes and join an *Astronomy* editor on this watch for the magical northern lights in the heart of Alaska. See you there!

Alaskan aurora photograph by Mike O'Leary

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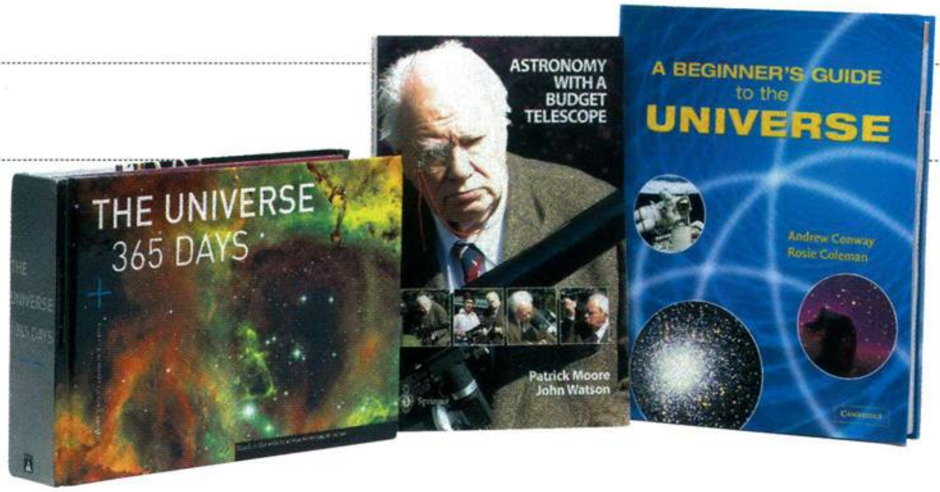
Everyday astronomy



The Universe: 365 Days

Robert J. Nemiroff and Jerry T. Bonnell, 740 pages, Harry N. Abrams, New York, 2003; ISBN 0–8109–4268–2; hardcover, $29.95.

French novelist Jules Verne took 19th-century readers around the world in 80 days in his book of the same name. Today, 130 years and innumerable technological advances later, armchair adventurers have *The Universe: 365 Days.*

To create this hefty coffee-table book, astronomers Robert Nemiroff of Michigan Technical University and Jerry Bonnell of the Compton Gamma Ray Observatory gleaned the best entries from six years of their highly successful web site, "Astronomy Picture of the Day" (APOD). Visited regularly by cosmophiles all over the globe since its inception in 1995, their award-winning site developed into a showcase of some of the most stunning images on the Internet.

This engrossing page-turner offers a different virtual destination for every day of the year, accompanied by captions that provide mini-lessons on topics from star birth to string theory.

In one image, a pair of yolky galaxies, arms outstretched, tumble toward each other. Destined to tear each other apart in a few billion years, they will create "tides of matter, lanes of dark dust . . . and streams of castaway stars." Similar forces pull at the Cigar Galaxy, which spurts crimson gas from its midsection as if wounded. Throughout the 4.5-pound tome, nebulae spin cloudy webs of candy-colored gas and dust.

The book also gives us impressive views closer to home: Orbiting observatories float above the clouds; the Moon eclipses the Sun in the Zambian sky; and a jet's silhouette streaks across the gray, roiling solar surface. Craggy blue-green rings of eroded rock in the Sahara Desert look alien from the Landsat 7 satellite drifting 400 miles overhead.

Clearly, Nemiroff and Bonnell made an effort to include not just the classic beauties of astronomy. The hazy and quirky, the microscopic — even the invisible — are among their most intriguing selections. A pebble next to what appears to be a large Idaho potato turns out to be the charming little moon Dactyl circling its mother asteroid, Ida. A ghostly 1970s photo snapped by the Soviet Lunokhod 1 robot as it roamed the Moon's surface shows us the Luna 17 spacecraft, one of Russia's great successes in space exploration. Fine lunar soil, which scientists believe erupted from a volcano nearly 4 billion years ago, looks like amber-colored droplets in microscopic view, and space glows neon-red and indigo when "seen" in long-wavelength radio waves.

The Universe: 365 Days is a treasure chest of astronomical images assembled by two men whose words convey their love of the cosmos. They succeed in creating here what the Web can't quite provide — a version of their archive you can flip open anywhere, coffee cup in hand, to leisurely lose yourself in space. — **JESSA FORTE NETTING** *writes about biology and astronomy in Los Angeles.*

Astronomy with a Budget Telescope

Patrick Moore and John Watson, 132 pages, Springer-Verlag, New York, 2003; ISBN 1–8523–3586–6; softcover, $19.95.

Moore and Watson's definition of a "budget" telescope is one available from a department store or mail-order catalog, produced by a manufacturer less well known than Celestron, Meade, or Orion, and priced under $400 (£300). The typical budget scope is a 2-inch or 3-inch refractor or a 4-inch or 5-inch reflector and includes one or two eyepieces, a small finder scope, and a tripod-based mount.

Hobbyists know quality optics *can* be found in this price range, but the category is rife with "trash" scopes. Ridiculous claims of high magnification and Hubble-quality views disappoint rather than inspire users. Even practical instruments often present a challenge for novices because their small apertures can collect only so much light.

Chapters on buying, assembling, and using small scopes address these issues with the aid of charts, tables, and full-color photographs in this easy-to-read text. Clear primers teach readers about celestial targets as well as how to navigate the night sky and understand spectral classes and separation.

Unfortunately, the book stops short of its potential. To ignore the major brands is to deny the reader great mail-order values. Affordable Mak-Cass, short-tube, and Dob-mounted units are hardly mentioned, and even simple light-path illustrations of different scope designs are missing. Basic component descriptions are too general to be of real use, and the reader is never told how to choose a good eyepiece or finder scope. References to budget-scope limitations early in the book make John Watson's concise introduction to astroimaging seem irrelevant.

However, when the authors move from equipment to observing, the writing relaxes, and the narrative is a joy to read. Yet this area, too, could benefit from tighter editing. Just one object is featured in each star map and its related text often lies pages away. Typos distract readers throughout the book, although only one actually gives misinformation, and by page 52, even the most optimistic amateur will know that a 2-inch tube doesn't have a 250mm-aperture lens.

The last few pages, which are devoted to an overview of more advanced scopes, segue nicely to further reading. Generous in recommending other books and some software, the writers likewise might have pointed readers to useful web sites.

Like the budget telescopes it describes, the text may get you into astronomy, but it leaves the distinct impression that other, more efficiently designed resources may do a better job. — **GLENN MULLER** *is a board member of the Hamilton Amateur Astronomers in Ontario, Canada.*

A Beginner's Guide to the Universe

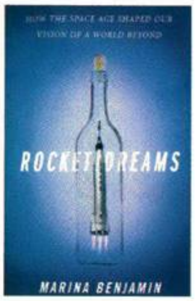
Andrew Conway and Rosie Coleman, 147 pages, Cambridge University Press, New York, 2003; ISBN 0–5218–0693–3; hardcover, $25.

Whether roving over the sand dunes of Mars or peering into glimmering nebulae, planetary probes and space telescopes regularly delight astronomy buffs with dazzling snapshots. Unfortunately, the science behind these celestial images often remains a mystery to youthful audiences. *A Beginner's Guide to the Universe* attempts to fill this vacuum with an appreciation of the weird and wonderful objects that populate the cosmos.

Andrew Conway, an astronomer at the United Kingdom's Open University, and Rosie Coleman, an elementary school teacher with 30 years' experience, teamed up to provide an excellent introduction to astronomy that leads readers from simple to complex topics in logical order. Aimed at an under-14 crowd (but great for adults who want to get an introduction to the field), the book starts with a primer on the sky and its landmark constellations. Subsequent chapters explore the solar system's worlds of fire and ice and deep-sky creatures such as stars, nebulae, and galaxies. Scotland's Astronomer Royal, John Brown, answers dozens of thought-provoking questions posed by schoolchildren in the last chapter, a section sure to satisfy the most curious young minds.

Brimming with facts, figures, stunning photographs, and amazing artwork, this comprehensive science book capitalizes on the best imagery available to draw in youngsters. Geared toward inquisitive 7- to 14-year-olds, most explanations are brief and simple, demystifying complicated topics such as star formation and extraterrestrial life. The authors successfully link concepts and terminology in an easily digestible and straightforward style.

Sorely missed, however, is a glossary of astronomical terms. The conservative, old-fashioned layout lacks some of the flashier computer-aided graphics now considered standard fare. Despite these design flaws, *A Beginner's Guide to the Universe* not only will capture the imaginations of many young space enthusiasts but also will whet their appetites for further learning. — **ANDREW FAZEKAS** *is an astronomy columnist and lecturer in Montreal.*



Rocket Dreams: How the Space Age Shaped Our Vision of a World Beyond

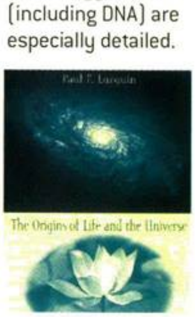
Marina Benjamin, 256 pages, Free Press, New York, 2003; ISBN 0–7432–3343–3; hardcover, $24.

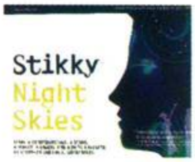
With all the space program has accomplished, it's easy to become complacent about what it hasn't. In this enchanting book, Benjamin, who as a child in the heady days of the 1960s believed she would be able to visit Saturn one day, questions why manned missions to the Moon and Mars lost steam. Looking for answers, she discovers our fascination with space simply found other outlets, such as the astronaut-founded mysticism of Noetics and cyberspace.

The Origins of Life and the Universe

Paul F. Lurquin, 218 pages, Columbia University Press, New York, 2003; ISBN 0–2311–2655–7; softcover, $27.50.

Readers may expect a book with a title as grand as this to be encyclopedic in size, but this slim volume covers a lot of ground in six short chapters. At times, this makes for scientifically dense text — the book sprung from the geneticist-author's lecture notes for an undergraduate course — but determined readers can get an overview of how the universe and the first life-forms may have taken shape. While various disciplines are covered, the biology sections (including DNA) are especially detailed.





Stikky Night Skies

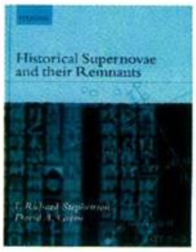
256 pages, Laurence Holt Books, New York, 2003; ISBN 1–5685–8253–6; softcover, $12.

If you're looking for the perfect book to convert the non-astronomers in your life to the hobby of observing, look no further. Part of a new series that employs psychological research into how people learn, this book guarantees readers will be able to identify six constellations, four stars, a planet, and a galaxy — all in an hour or less. Its appeal lies in its simplicity and interactivity. Each page features a sentence or two that highlights a single concept, and questions posed on one page are answered on the next. You can't help but turn the page, making this a book you'll have no problem finishing.

Historical Supernovae and their Remnants

F. Richard Stephenson and David A. Green, 272 pages, Oxford University Press, New York, 2002; ISBN 0–1985–0766–6; hardcover, $120.50.

Setting out to update the 1977 precursor to this book, the authors write they "anticipated that little progress might be possible on the historical front," since the early sources apparently had been so well plumbed. Not so. New sources, as well as more sophisticated interpretations of old ones, have shed a surprising amount of light on the five stellar explosions observed before the advent of telescopes. The book also discusses unconfirmed supernova candidates.



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The White Sands Star Party (WSSP)

offers stargazers a unique opportunity to view the heavens from one of America's national treasures — White Sands National Monument. The New Mexico Museum of Space History and Alamogordo Astronomy Club will host this fifth annual star party, located near Alamogordo, New Mexico.

THE PLEIADES, M45, will remind star party attendees in the Northern Hemisphere that winter is right around the corner. JOHN CHUMACK

WSSP participants will enjoy special considerations that other park visitors lack, including speakers, camping privileges, and tours of nearby National Solar and Apache Point Observatories.

For more information, contact the WSSP committee at wssp@zianet.com; web site, www.zianet.com/wssp/.

08.29.03–09.01.03

Arunah Hill Days

Arunah Hill Natural Science Center, Cummington, Massachusetts. For more information, visit Arunah Hill's web site, www.arunah.org/.

08.26.03–08.27.03

Cathedral Gorge Campout

Cathedral Gorge State Park, Panaca, Nevada. For more information, e-mail cathedralgorge@hotmail.com; web site, www.ccsn.nevada.edu/LVAS/.

08.29.03–09.03.03

European Symposium on Occultation Projects

Michael Adrian Observatory, Trebur, Germany. For more information, visit www.esop2003.t1t-trebur.de/.

08.01.03

Lake Bob Sandlin State Park Labor Day Star Party

Lake Bob Sandlin State Park, Pittsburg, Texas. For more information, contact Thomas Williamson at 817.656.0901, 7005 Southampton Rd., North Richland Hills, Texas 76180-4433; e-mail, Will02@airmail.net; web site, www.whitney-astro.com.

09.18.03–09.21.03

Astrofest

Camp Shaw-waw-nes-see, Manteno, Illinois. For more information, contact Walter Glogowski at 847.784.8510; e-mail, wglogowski@ameritech.net; web site, chicagoastro.org/af/index.html.

09.19.03–09.21.03

Astro-Tour

Ballreich Observatory, Tiffin, Ohio. For more information, contact Tom at 419.797.4854; web site, www.friendlynet.com/astronomy/.

09.19.03–09.21.03

Idaho Star Party

Bruneau Dunes State Park Observatory, near Mountain Home, Idaho. For more information, contact Chris Erwin at cserwin@cableone.net; web site, www.boiseastro.org/isp.htm.

09.21.03–09.27.03

Okie-Tex Star Party

Camp Billy Joe, near Kenton, Oklahoma. For more information, visit www.okie-tex.com/.

09.23.03–09.28.03

Astroblast

Oil Region Astronomical Observatory, Two Mile Run County Park, near Franklin, Pennsylvania. For more information, visit www.oras.org/.

09.23.03–09.28.03

Great Plains Star Party

Edge of the Kansas Flint Hills, 73 miles southwest of Kansas City, Missouri. For more information, contact Robert Nederman at 913.888.7744; web site, www.astronomyvillage.com.

09.24.03–09.28.03

No Frills Star Party

Tuckahoe State Park, Queen Anne, Maryland. For more information, contact Lyle Jones at 302.736.9842; e-mail, lyjones@state.de.us; web site, www.delmarvastargazers.org/.

09.24.03–09.27.03

Southern New Mexico Star Party

City of Rocks State Park, Faywood, New Mexico. For more information, contact the National Public Observatory, P.O. Box 19, Radium Springs, New Mexico 88054; e-mail, jgilkiso@zianet.com; web site, www.upstateastro.org.

09.25.03–09.28.03

Alberta Star Party

Eccles Ranch Observatory, Caroline, Alberta, Canada. For more information, contact Roland at 403.246.4498; e-mail, dechesne@telusplanet.net; web site, www.syz.com/rasc/asp.htm.

09.25.03–09.28.03

Enchanted Skies Star Party

Sorroco, New Mexico. For more information, call 505.835.0424; e-mail, chamber@socorro-nm.com; web site, www.socorro-nm.com/starparty/.

09.25.03–09.28.03

Huronia Star Party

Camp Soulaine, near Ivy, Ontario, Canada. For more information, contact Gord Rife at 905.939.2836; web site, www.cois.on.ca/~ssaa/.

09.25.03–09.28.03

Northern Lights Astronomy Festival

HighBridge Hills Educational Center, Granite Ridge, Wisconsin. For more information, call 715.360.5539; web site, www.starscamp.com/.

09.26.03–09.28.03

Great Lakes Stargaze

River Valley R.V. Park, near Gladwin, Michigan. For more information, contact Joe at 989.662.0178; e-mail, jbruessow@chartermi.net; web site, www.boonhill.net/sunset/index.htm.

09.27.03–09.29.03

Whirlpool Star Party

Doolys Hotel, Birr, County Offaly, Ireland. For more information, visit www.geocities.com/shannonsideac/whirlpol.htm. ■

CONTACT INFORMATION

Please submit club announcements four months in advance to Coming Events, *Astronomy*, P. O. Box 1612, Waukesha, WI 53187, or jmcgovern@astronomy.com. Add your events to our on-line calendar at www.astronomy.com.

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RESOURCES

Learn more about this issue's topics

30 YEARS OF GREAT STORIES

ARTICLES — The August 1998 issue of *Astronomy* contained several articles that looked at important breakthroughs since the magazine's inception in 1973. In particular, "The Great Solar System Revision" by William K. Hartmann explored how pioneering space missions totally changed our view of the planetary system we call home. And in "Telescope-Making Revolution," Richard Berry told the story of how advances in design and technology utterly transformed the way backyard astronomers observe the universe.

MOUNT WILSON

BOOKS — Read Hubble's account of how the nature of galaxies (or "spiral nebulae" in now obsolete terminology) was discovered in *The Realm of the Nebulae* by Edwin Hubble (Yale University Press, New Haven, Connecticut, 1936). Donald Osterbrock's *Pauper and Prince: Ritchey, Hale, & Big American Telescopes* (University of Arizona Press, Tucson, Arizona, 1993) provides an absorbing look at the interactions of two complex personalities — George Ellery Hale, the funding impresario, and George Ritchey, the designer and builder of big telescopes.

You'll find a beautiful picture book illustrating the galaxy types Hubble devised in *The Hubble Atlas of Galaxies* by Allan Sandage (Carnegie Institution of Washington, Washington, D.C., 1961). The classic biography of Hale is Helen and Henry Wright's *Explorer of the Universe* (Springer-Verlag, New York, 1994).

For a look at Hale's life and work recorded in contemporary documents and photographs, along with essays assessing his scientific work and his impact on astronomy, see *The Legacy of George Ellery Hale* edited by Helen Wright, Joan N. Warnow, and Charles Weiner (MIT Press, Cambridge, Massachusetts, 1972).

WEB — The Mount Wilson Observatory has its own web site at www.mtwilson.edu. The site contains a lot of interesting and useful information.

CAMELOPARDALIS AND URSA MINOR

BOOKS — A must-have for any dedicated Northern Hemisphere observer is *Uranometria 2000.0 Deep Sky Atlas Volume I: The Northern Hemisphere to –6°* edited by Wil Tirion, Barry Rappaport, and Will Remaklus (Willman-Bell, Richmond, Virginia, 2001). *The Photographic Atlas of the Stars* by H. J. P. Arnold, Paul Doherty, and Patrick Moore (Kalmbach Publishing Co., Waukesha, Wisconsin, 1997) is a helpful tool for finding the faint stars of Camelopardalis and other inconspicuous constellations. The book partners star maps with color photographs of all 88 constellations, matching each map to what an observer really sees when looking up.

THROUGH ANDROMEDA, DEEPLY

ARTICLES — The Hubble Space Telescope's first foray deep into the universe came in December 1995, when the Wide Field and Planetary Camera 2 pointed at one tiny region of the cosmos for ten consecutive days. The story of the Hubble Deep Field appeared in "Approaching the Edge of Space and Time" by Robert Naeye (*Astronomy*, April 1996).

THE YOSEMITE STAR PARTY

WEB — In addition to the Yosemite National Park Internet address provided in the article, each of the following California astronomy clubs is involved in the Yosemite Star Party: Eastbay Astronomical Society (Oakland), www.eastbayastro.org; MIRA Observers Group (Monterey), www.mira.org; Mount Diablo Astronomical Society (Concord), www.mdas.net; Peninsula Astronomical Society (Mountain View), www.foothill.fhda.edu/ast/pas.htm; San Francisco Amateur Astronomers (San Francisco), www.sfaa-astronomy.org/sfaa; San Jose Astronomical Association (San Jose), www.sjaa.net; Santa Cruz Astronomy Club (Santa Cruz), astro.santa-cruz.ca.us; Tri-Valley Stargazers (Livermore), www.trivalley stargazers.org; Valley of the Moon Astronomical Society (Glen Ellen), www.vmoa.kenwood.ca.us.

CCD IMAGING

BOOKS — For a good overview of CCD technology, try Steve B. Howell's *Handbook of CCD Astronomy* (Cambridge University Press, New York, 2000). For an advanced look into CCD systems, try *CCD Arrays, Cameras, and Displays* by Gerald C. Holst (Society of Photo-optical Instrumentation Engineers, Bellingham, Washington, 1998).

WEB — To learn more about astronomy's connection with CCDs and to see some terrific examples of images, visit Ed Grafton's Internet site at www.ghg.net/egrafton. Grafton is an amateur astronomer who images with a Celestron C11 from his home in Houston, Texas. Another, more comprehensive site is Ron Wodaski's page at www.newastro.com/newastro/default.asp. Wodaski, who has maintained this web site for years, offers a number of services on-line. You can purchase a copy of his book, *The New CCD Astronomy*, download software, or even sign up for a CCD imaging camp.

SOLAR FILTERS

BOOKS — An excellent guide for sunwatchers is *Observing the Sun* by Peter O. Taylor (Cambridge University Press, New York, 1991). A slightly more in-depth look at solar phenomena is presented in *Storms from the Sun* by Michael J. Carlowicz and Ramon E. Lopez (Joseph Henry Press, Washington, D.C., 2002). For just about any detail about the Sun or how to observe it, read *Solar Astronomy Handbook* by Rainer Beck, Heinz Hilbrecht, Klaus Reinsch, and Peter Volker (Willmann-Bell, Richmond, Virginia, 1995).

WEB — For the very latest solar images in many wavelengths, visit the on-line site of the Solar Data Analysis Center, part of NASA's Goddard Space Flight Center, at umbra.nascom.nasa.gov:80/sdac.html. Another excellent Internet site is the Solar Terrestrial Dispatch at www.spacew.com. ■

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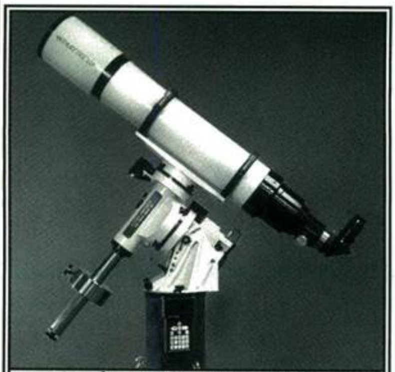

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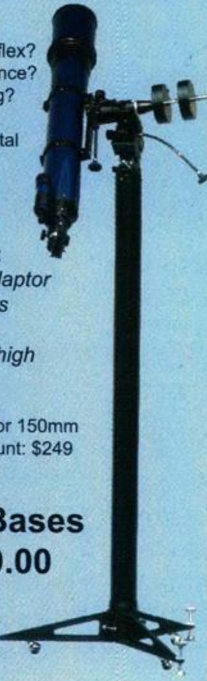

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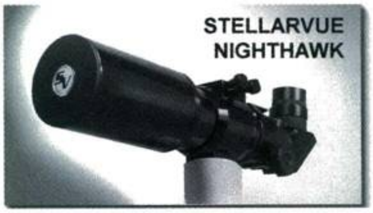

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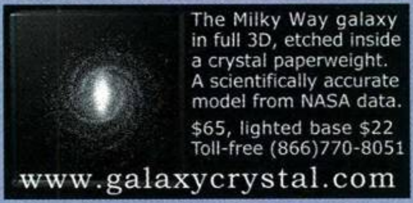

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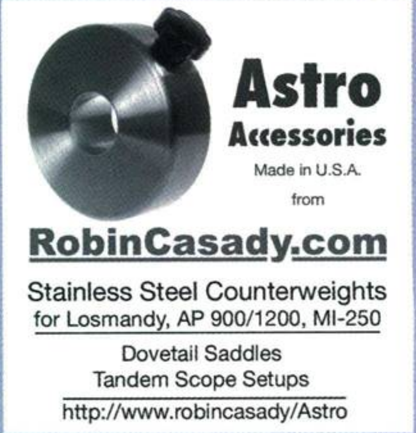

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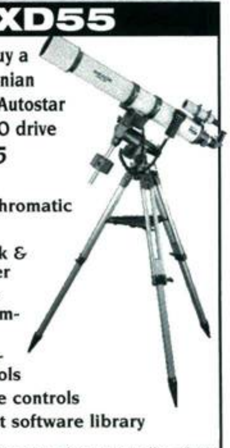

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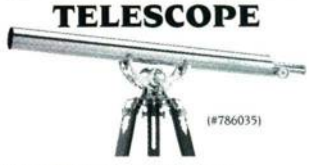

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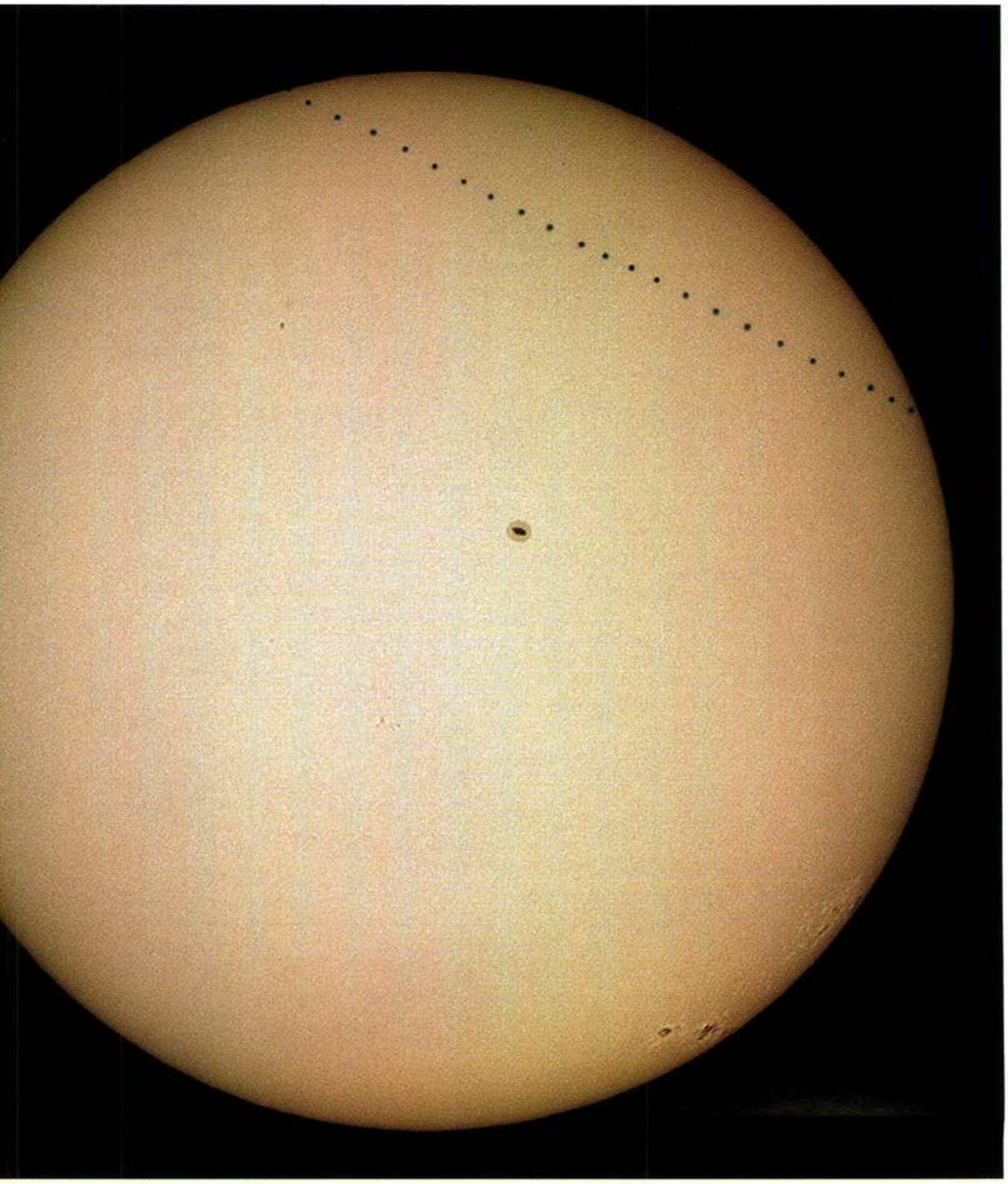
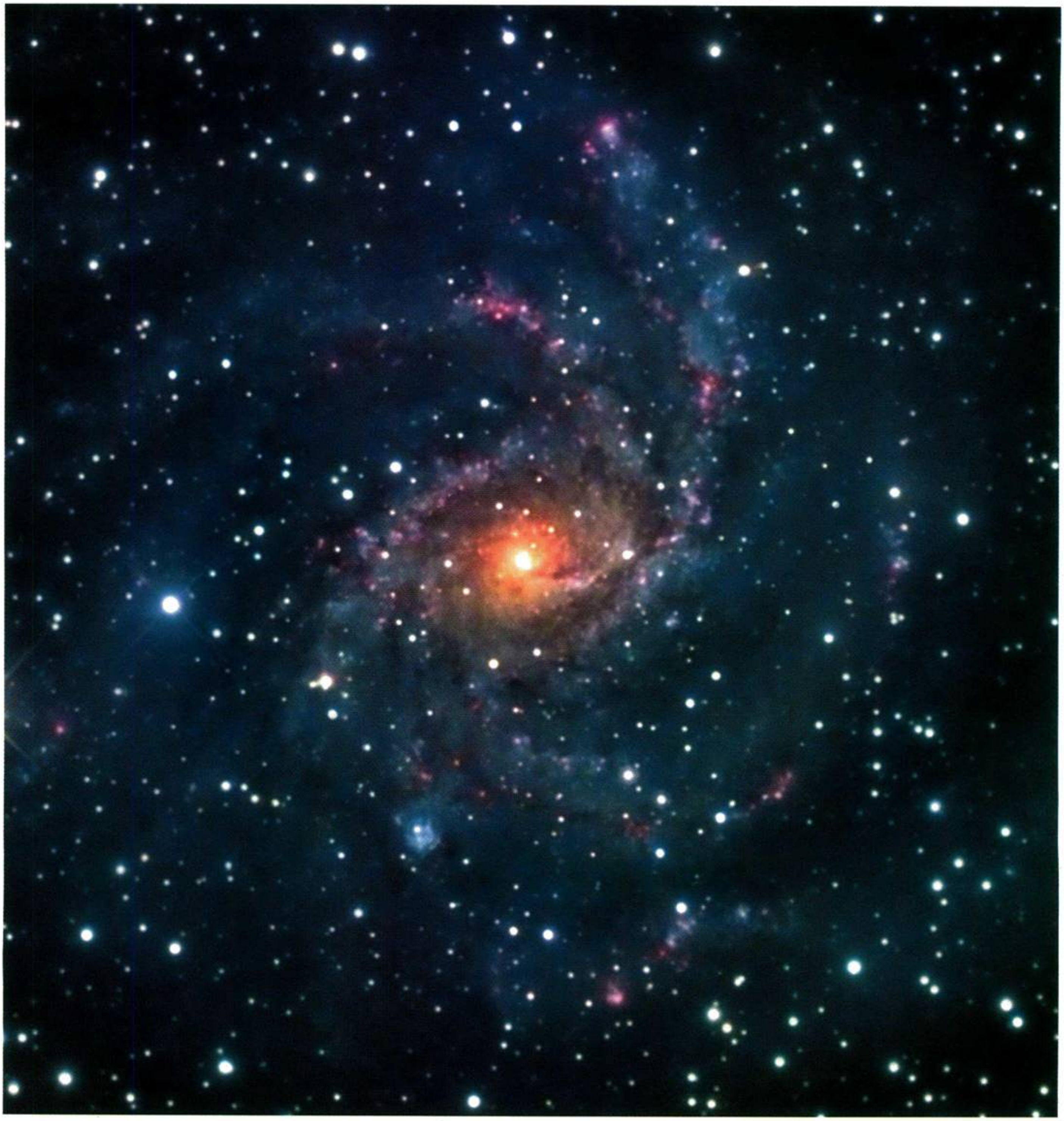


EARTH'S ORBIT

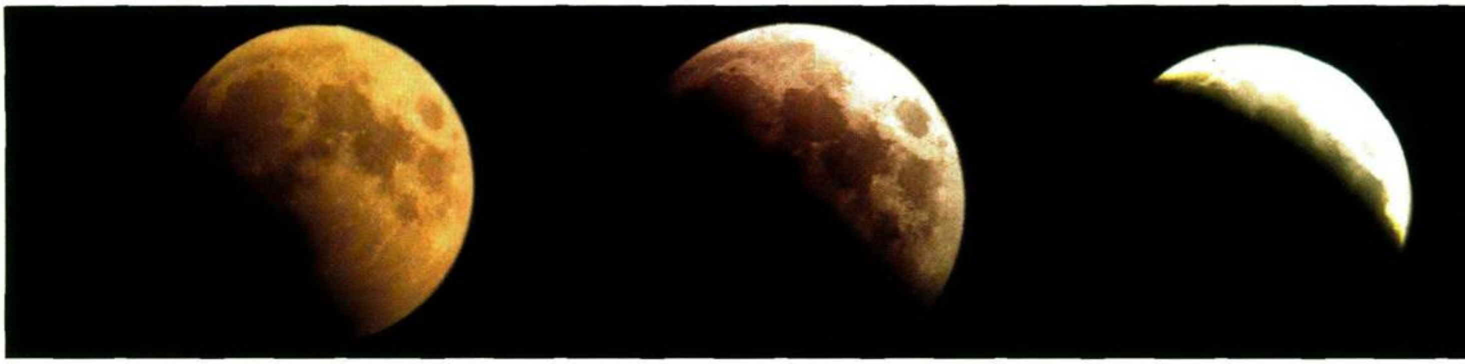
A transit of Mercury

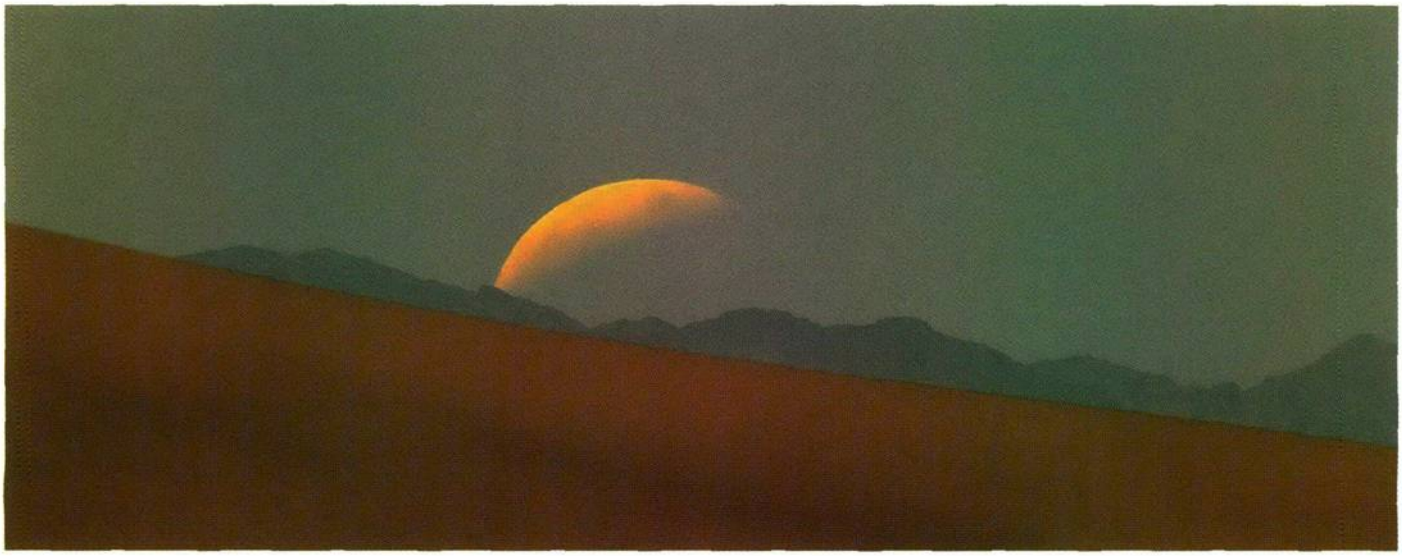
Four times a year, Mercury passes between the Sun and Earth. Because the plane of Mercury's orbit is not the same as ours, Mercury usually passes invisibly either above or below the Sun. Occasionally, however, Mercury's path takes it directly between the Sun and Earth, creating an event called a *transit*. At such times, viewers can see the small disk of Mercury silhouetted against the brilliant face of the Sun. The most recent transit of Mercury took place on May 7 of this year. The previous transit occurred on November 15, 1999, and the next one will not occur until November 8, 2006.

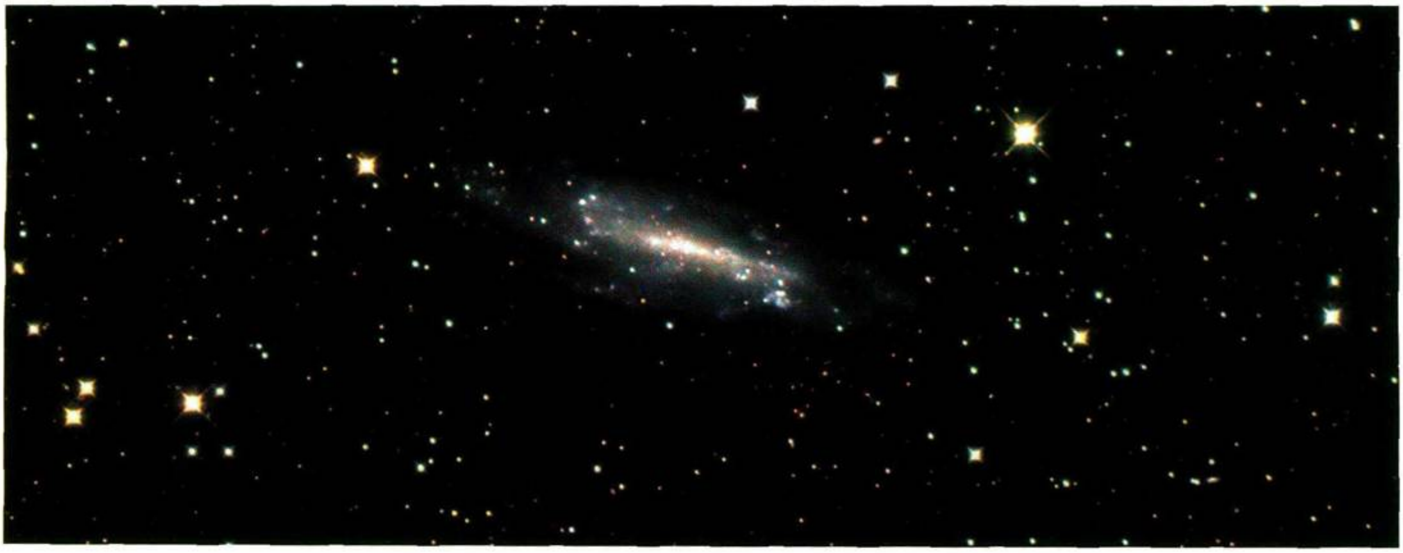
Left, **TRANSIT OF MERCURY SEQUENCE** [Astro-Physics 6-inch EDFS refractor at f/7, Baader solar foil filter, Nikon D100 digital camera, 23 images taken approximately 15 minutes apart, superimposed on a single frame, May 7, 2003, from Ghent, Belgium] /// **DOMINIQUE DIERICK**



Above, **SPIRAL GALAXY NGC 6946 IN CEPHEUS** (12.5-inch Optical Guidance Systems Ritchey-Chrétien telescope at f/9, ST10-XME CCD camera, LRGB image with exposures of 270, 20, 20, and 30 minutes, respectively) /// **ROBERT GENDLER**





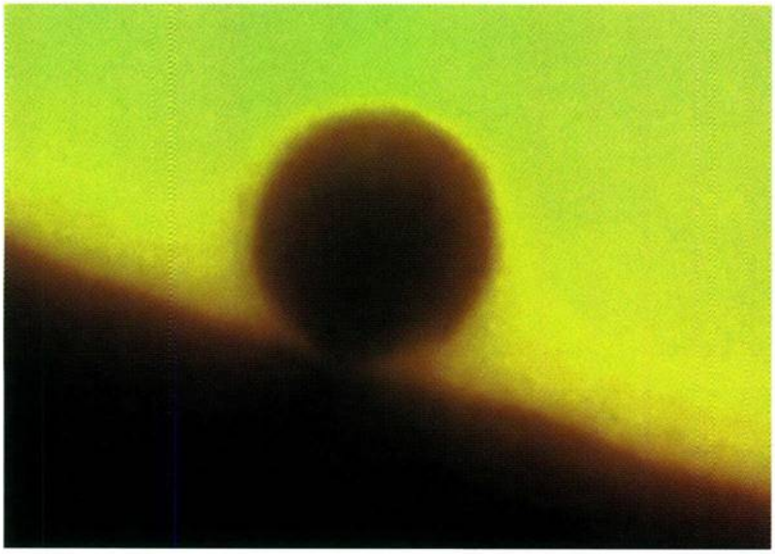


Top sequence, **A LUNAR ECLIPSE SEQUENCE** (Meade 10-inch Starfinder at f/4.5, Olympus OM-2 camera, Kodak High Definition 400 film, 8:10 to 10:30 P.M. MDT, May 15, 2003, from El Paso, Texas) /// **RUDY AND JACOB HERNANDEZ AND BLANCA SORIA**

Center, **THE ECLIPSED MOON RISES OVER DEATH VALLEY** (Canon 500mm, f/4 image stabilized lens at f/11, Canon 1Ds digital SLR, 1/13-second exposure taken 7:55 P.M. PDT, on May 15, 2003) /// **MICHAEL H. REICHMANN**

Bottom, **SPIRAL GALAXY NGC 4236 IN DRACO** (Takahashi Epsilon 210 8-inch, f/3 Astrograph, SBIG ST-2000 XM/CFW-8 CCD camera, luminance exposure of 35 minutes, RGB exposures of 5 minutes each) /// **RICHARD JACOBS**

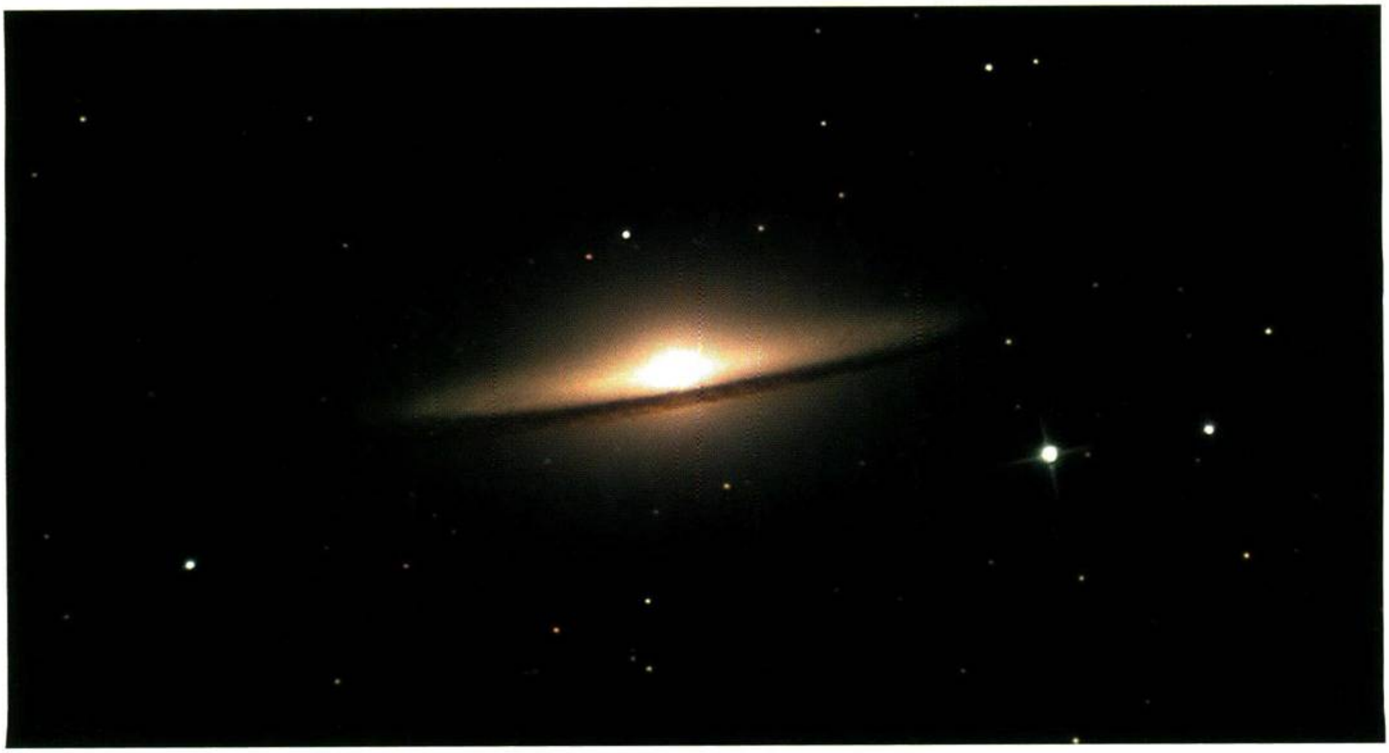
Send your photos to: ASTRONOMY Reader Gallery, P.O. Box 1612, Waukesha, WI 53187; e-mail to readergallery@astronomy.com.
Please include your full name, date and location of image, and complete photo data: telescope, camera, film, and exposure information.

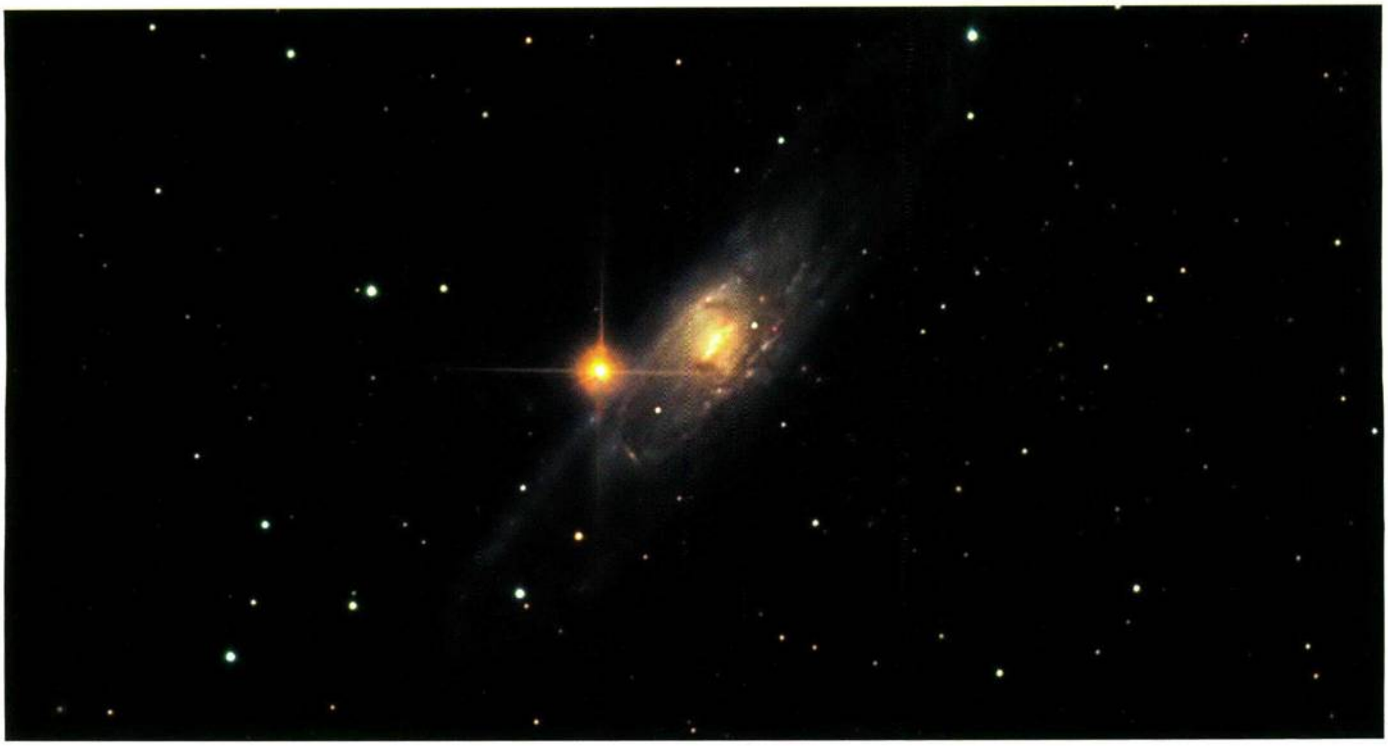


Center left, **THE BLACK DROP** is an optical effect that occurs during transits of Mercury and Venus. [6-inch Sky-Watcher refractor, Sony TRV 740E videocamera, taken May 7, 2003, 12:23:04 UT, from Witten, Netherlands] /// **RALF VANDEBERGH**

Center right, **LUNAR ECLIPSE** [TeleVue Genesis 4-inch refractor at f/5, SBIG ST-10 MXE CCD camera, LRGB image with exposures of 2, 8, 8, and 13 seconds, respectively, taken May 16, 2003, from St. Raymond, Quebec, Canada] /// **JEAN GUIMOND**

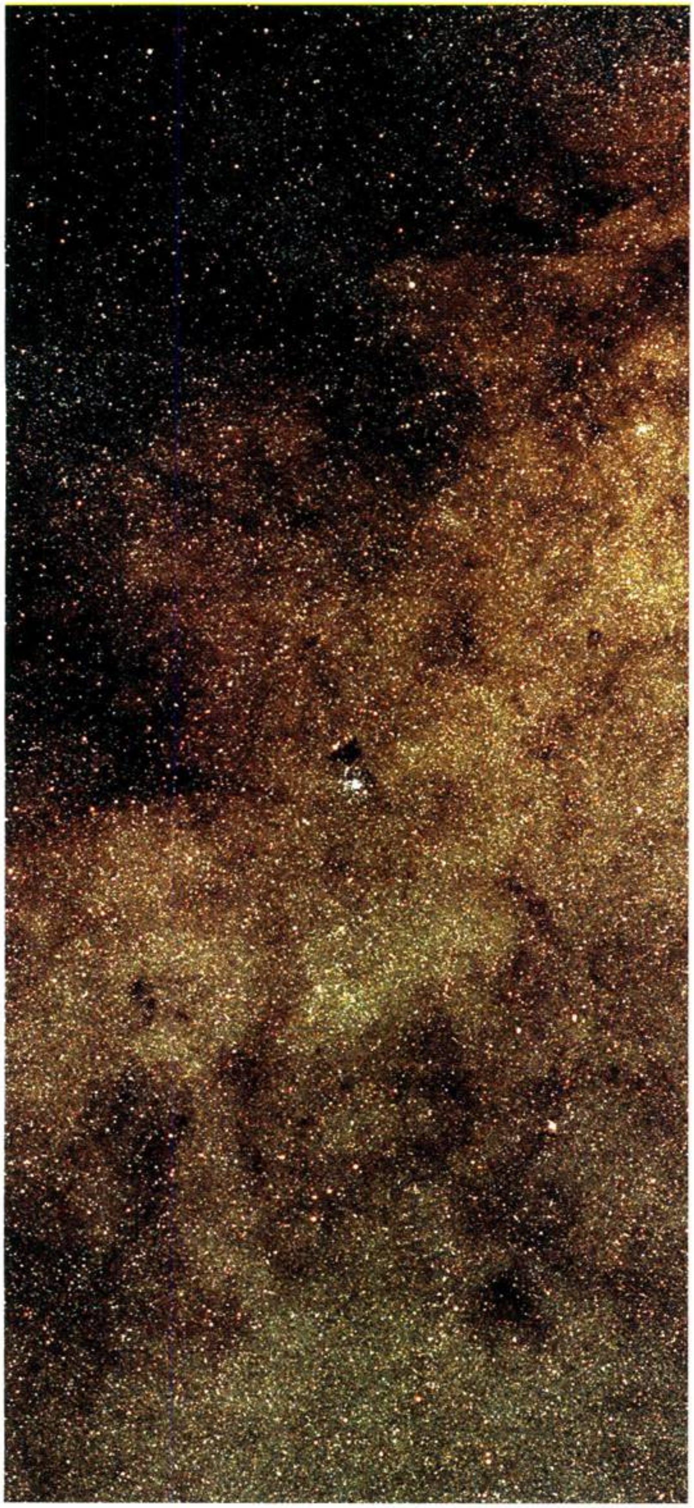
Bottom, **IC 4592 AND IC 4601 IN SCORPIUS** [AstroPhysics 6-inch, f/7 EDF refractor, Byers Series II mount, digital composite of three 45-minute exposures on hypered 120-format Kodak PPF Pro 400] /// **GEORGE GREANEY**

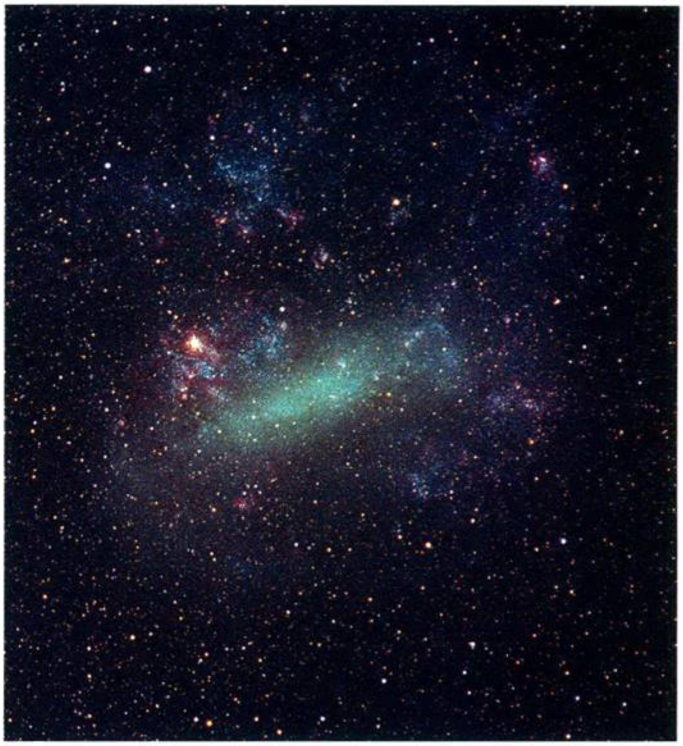


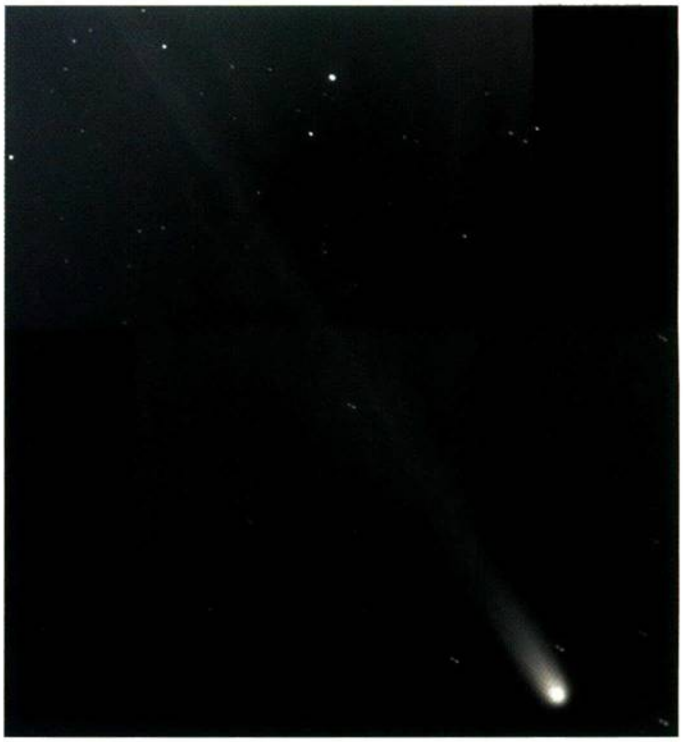


Top. **THE SOMBRERO GALAXY (M104) IN VIRGO** [Takahashi Mewlon 300 12-inch Dall-Kirkham reflector at f/9.1 [using focal reducer], SBIG ST-10XME CCD camera, LRGB image with exposures of 60, 30, 30, and 30 minutes, respectively, taken April 30, 2003, at the Texas Star Party, Fort Davis, Texas] /// **RANDY BREWER**

Above. **SPIRAL GALAXY NGC 5792 IN LIBRA** [20-inch RC Optical Systems Ritchey-Chrétien telescope at f/9, SBIG ST10-XME CCD camera, LRGB image with exposures of 80, 20, 20, and 20 minutes, respectively, taken June 6, 2003, from Kitt Peak National Observatory, 56 miles southwest of Tucson, Arizona] /// **BRAD EHRHORN/NOAO/AURA/NSF**





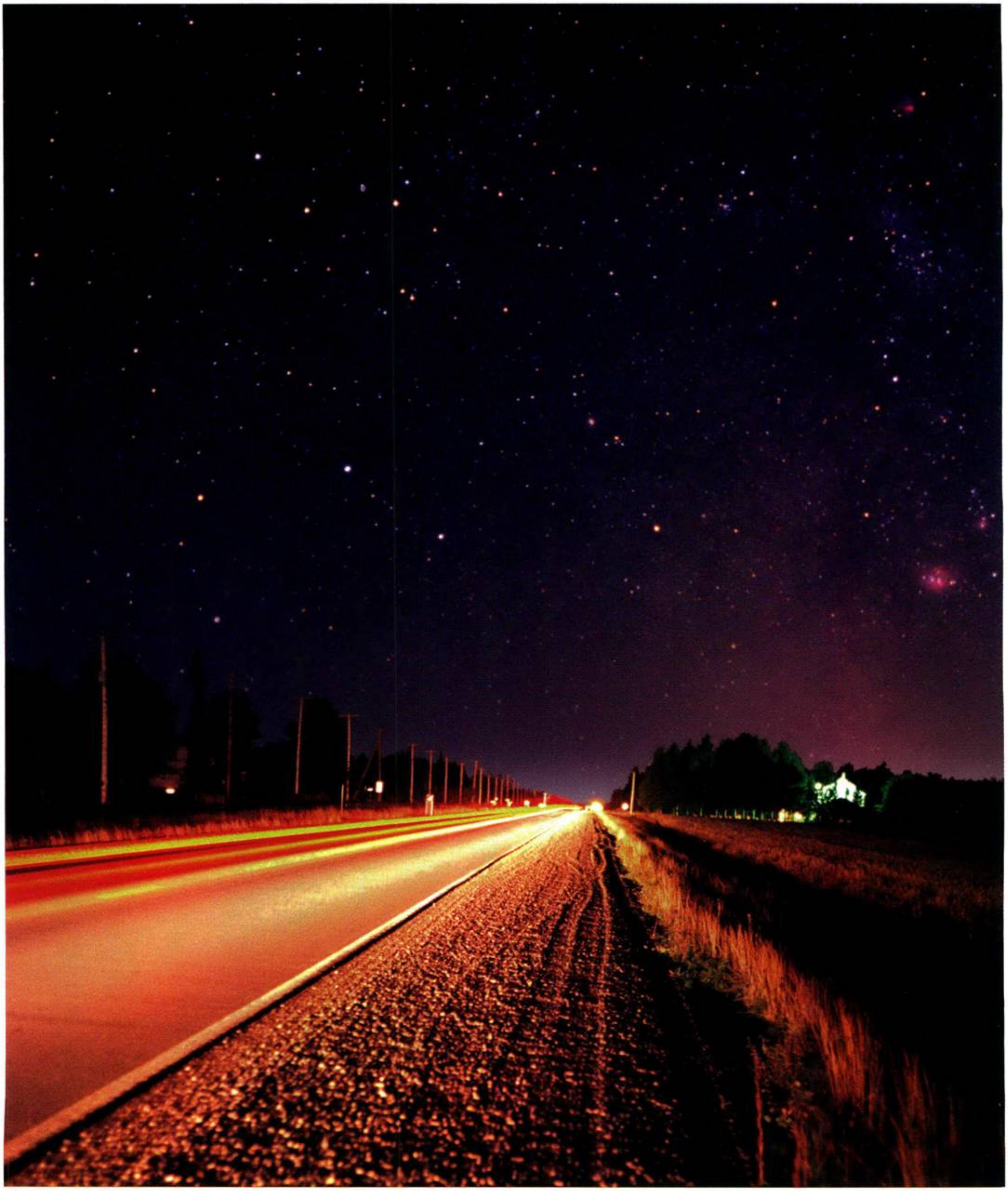


Above, **THE INK SPOT NEBULA (B86) IN SAGITTARIUS** (Meade 12/16-inch Schmidt camera at f/2.2, Kodak PPF 400 film, composite of two 7-minute exposures, taken May 31, 2003, from Plano, Texas) /// **JASON WARE**

Top right, **THE LARGE MAGELLANIC CLOUD** (135mm lens at f/4.5, 60-minute exposure, Kodak ProGold 400 GPY film, taken October 15, 1998, at the Niedersachsen guest farm, Namibia) /// **ANDREAS B'KER AND AXEL MARTIN**

Bottom right, **COMET C/2002 V1 NEAT MOSAIC** (Meade 8-inch LX-90 at f/2.8, Starlight Xpress MX716 CCD camera, 15 exposures of the head and 4 of the tail were combined, taken February 7, 2003, in Hampshire, Illinois) /// **DENNIS PERSYK**

Below, **THE ROAD TO NIRVANA** [composite of the summer night sky [3 minutes] and a country road [30 seconds], Canon EOS-3, 28mm lens, Kodak Royal Gold 400 film, taken near Quebec, Canada] /// **JAY OUELLET**



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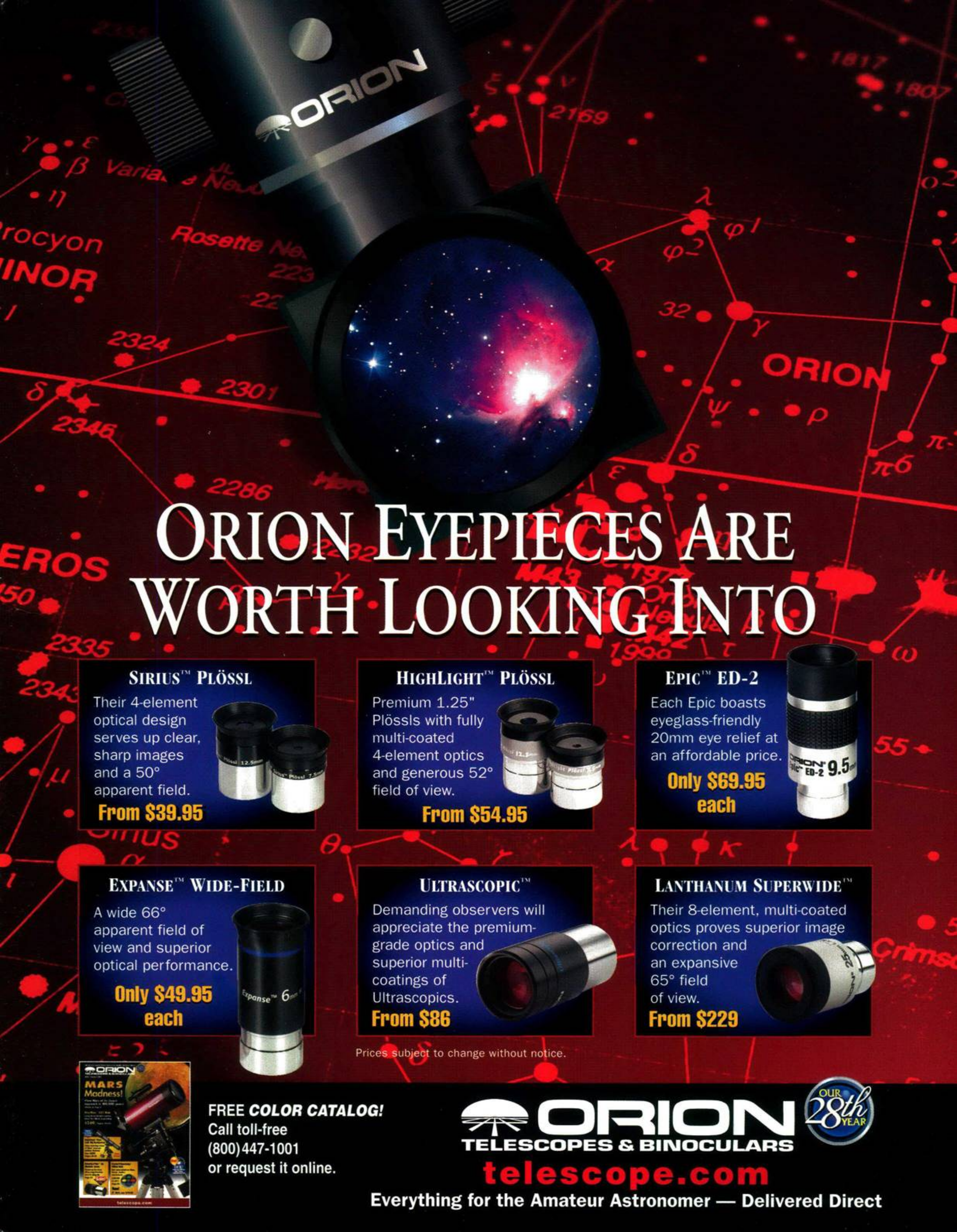

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